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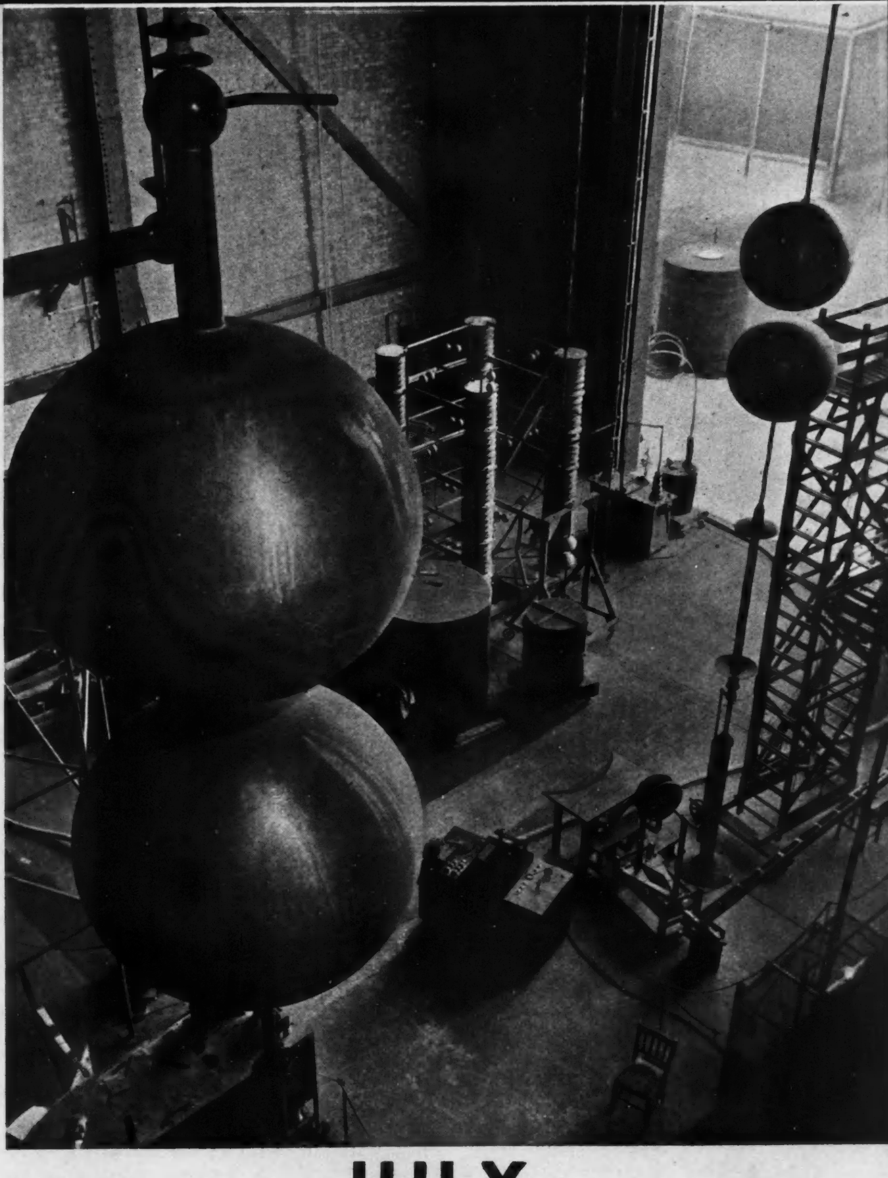

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The Progress of Science

A MONTHLY NOTEBOOK COMPILED UNDER THE DIRECTION OF DAVID S. EVANS

Mission to Moscow

THE prospect of about thirty leading British scientists attending the meeting of the Academy of Sciences in Moscow was one that stirred the imagination, for here was a real chance of pumping some good red blood—the colour is not intended to have any political significance—into the somewhat flaccid arteries of scientific liaison between this country and Russia. *The Times* wrote a nice little leaderette on the topic, and one would have thought that Britain would not have contained a single person to object to the despatch of this important mission to Moscow. But before that issue of *The Times* had reached the breakfast table the Caretaker Government had stepped in to prevent eight of the scientists from leaving the country. What the true reason was for this high-handed action—and to use the device of refusing exit permits was high-handed in the extreme and a despicable way of "persuading" eight top-flight scientists to stay behind—we do not know as we write this note. Some may accept the Government's explanation, that the scientists were too important to the war effort to be allowed out of the country, even for the short period of ten days. No security reasons were involved, said Mr. Churchill in the House of Commons. (One would hope not; the Russians are still our allies, and great play has been made, particularly in British propaganda, about the mutual interchange of scientific and technical knowledge between the United Nations.)

If that explanation is acceptable then it becomes possible to say, as *The Chemical Age* has said, that the whole thing was "a fantastic piece of mismanagement" and "an extraordinary instance of official maladroitness."

We should like to be able to accept the explanation at its face value. So, too, presumably would Professor A. V. Hill, but writing in *Nature*, he comments: *Many readers will have been astonished and repelled by the studied discourtesy with which eight of the intending guests of the Soviet Academy of Sciences were prevented by His Majesty's Government from going to Moscow. Not only were they put to gross inconvenience and annoyance by the refusal, without warning and at the last moment, of permission to travel, but also the explanation given was as incredible as the real reason was insulting.*

Professor Hill is one of the Secretaries of the Royal Society, and the Royal Society had had much to do with the arranging of the Moscow Mission, so it is likely that Professor Hill knows what the real reason was. We can only guess at it, and then the only conclusion possible is a very unpleasant one: one can scarcely believe that our Government could choose to be so grossly insulting.

Two insults—unintentional, perhaps—have been conveyed, one to the Russians, and the other to the scientists. Should the Government ever choose to apologise for these insults—one hopes they were innocently and thoughtlessly perpetrated and that they did not arise in the application of a carefully considered policy—they might also choose to issue a denial of the story, that has gained some credence as a result of the "mission to Moscow" incident, to the effect that recently strong pressure was put upon the Australian Government by the British Foreign Office in an attempt to stop them sending Professor Ashby to Moscow as a scientific attaché.

Freedom to travel and freedom to exchange scientific information with their fellows are rights that scientists have foregone during the war. These freedoms need to be restored as rapidly and as completely as possible once security allows. British scientists have a special claim on the limited travelling facilities available at the moment for they can render incalculable service in the renaissance of science and culture that started when the continent, country by country, was liberated from the Nazi tyranny. For half a decade Europe has been starved of news about British scientific progress. The eagerness with which European scientists who come to Britain collect details of this progress not only for themselves but for their colleagues is in its own way almost as embarrassing to us here as are the photographs we see of Europe's emaciated children. Starvation in intellectual matters is just as real as that due to lack of food, and no time should be lost in meeting the needs of Europe's scientists and scientists-to-be. We hope to see more reports of the kind that told us that Professor A. V. Hill had left for Copenhagen to convey the greetings of the Royal Society as representing the men of

science in Britain to their colleagues in Denmark, and to discuss with them what aid British science can give to the rehabilitation of science and scientific education in their country. After spending three days in Copenhagen, Professor Hill proceeded to Norway for the same purpose. What store European scientists put by such visits is indicated by the fact that the Norwegian Academy of Sciences called an extraordinary meeting so that as many people as possible might meet Professor Hill. The Government must be prepared to do everything it can to facilitate more visits of this kind, and by exhibiting generous and genuine sympathy towards the scientific needs of Europe and the desire of British scientists to make a full contribution to the restoration of science on the continent it could make amends for the miserable meanness of motive and action that kept eight scientists behind when they ought to have been in Moscow.

V Weapons: What of the Future?

It is often said that the speeches made in the House of Lords are less encumbered with purely debating points than those made in the Commons, and that there is often more of an air of authoritative knowledge and disinterested desire for truth than in the Lower House. Remarks of this kind are usually a preliminary to a defence of the existence of the House of Lords, but with that question we are not concerned: we are merely concerned with business transacted in the House of Lords on May 29 and 30, when the speeches dealt with subjects which are of general concern to the public and of particular interest to scientists.

On the first day Lord Vansittart raised the question of the control of German war inventions. He took the line that further aggression could, in any event, be expected from Germany and that weapons even more deadly than V1 and V2 could be developed in secret. He asked for stringent control and inspection of all German laboratories, both industrial and university. The actual words of his motion were "To ask His Majesty's Government whether they will take the initiative in proposing to the Allied Governments the inclusion in the terms imposed upon Germany of an article providing that a permanent Inter-Allied Committee of Scientists should be established to examine and control, and if necessary to prohibit the use by Germany of any scientific discovery or invention considered dangerous to the safety of mankind."

During his speech he went further and suggested that the inspectorate might in due course become a world inspectorate to guard against development, or over-development of secret devices. He was supported by Lord Strabolgi who raised such points as the present system of international holding of patents by cartels, described the effective work done by the United States Custodian of Enemy Property in unearthing enemy patents, and supported him in a demand for a world wide inspectorate. He made one excellent point: "I do not think that wars are made because someone discovers some terribly lethal poison gas or some new kind of rocket. I believe that wars come from quite different causes; . . . You can blame the scientists for allowing their talents to be prostituted for the use of the war-makers, but you cannot blame the scientists for making the wars. It is the war-makers who make the wars, and they coerce or persuade to bribe the scientists into helping them. You may say 'More shame to the scientists' but there it is."

The reply for the Government was made by Lord Cherwell who began by drawing a distinction between pure science and its applications, particularly its war-like applications, and these he preferred to describe as "engineering". He describes how the level of German science had greatly deteriorated under the Hitler régime, and remarked that the scientific devices, including radar, used by the Germans, depended on no new scientific principle. The Germans had been able to make progress because they had taken care to secure a very high output of well-trained and capable engineers. Lord Cherwell developed this argument, using a number of scientific examples, and pointed out the impossibility of foreseeing possible applications of new scientific principles, since so often in the past one and the same principle proved applicable both to weapons of destruction and to important beneficial developments for peace.

In conclusion, he assured the house that a committee of scientists had been appointed to consider the whole question of the future of scientific research in Germany, and that this, like all other German activities, would come under measures of control agreed between the Allies.

Next day Lord Brabazon of Tara rose to call the attention of the Government to the future of "directed missiles." After a short survey of the history of warfare he passed to a consideration of rocket and jet propelled missiles, and pointed out the extreme cheapness with which V1 was produced. He referred also to V2 and stressed the fact that this weapon was only in its infancy and might acquire a much increased range and a greater explosive power, for example by the introduction of "explosives of an atomic type." Finally he called attention to the possibility that in ten years' time the sternness of Germany's occupation might be wearing off, and that then opportunity might be seized to manufacture new weapons of this kind in underground workings—ostensibly mine-shafts—sunk in remote parts of the country. He said, "I most earnestly plead that in the organisation for peace there should be given to some international committee power which will allow them to enter anywhere in the world at any time to see what people are up to." His final words were, "There are only two ways of dealing with this awful position. One is that in combination with America we should pursue the technical problems with vigour and get ahead of the world steadily. The other way is to invent machinery of inspection to stop the possibility."

Again Lord Cherwell replied for the Government. He was particularly concerned with the efficacy of the V-weapons in relation to their expense, and he may have given their Lordships some comfort with the remark that "another general proposition which will scarcely be denied is that it is much easier to hit the target from a short distance than from a great distance. *A priori*, therefore, the air bomber, who releases his bombs within less than ten miles of his target, will have a great advantage over the artilleryman (in the widest sense) who fires at a distance of a hundred miles or more. The factor of advantage in that case—ten miles to one hundred miles—is 100. This is an absolutely general proposition and is bound to be true as long as Euclid's axioms are valid." Thirdly he pointed out the reduction in warhead necessitated by an

increase in the range of such weapons. The range of V1 was about 140 miles, and that of V2 about 200 miles; to increase the range to 280 miles, using the same total carcass weight and fuels, would involve reducing the warhead to 500 lbs.

Lord Cherwell then pointed out that the R.A.F. developed weapons similar to V1 many years ago; they were dropped because there were no targets available to us of the exceptionally large and dense character of Greater London. V1 was cheap, but even so only one hundred could be produced for the cost of a bomber; its range was limited, and its accuracy only one tenth of that of a bomber bombing through cloud. Only one third of the missiles launched reached the target. V2 was ten or twenty times as expensive as V1 and was not notably more accurate: "only in a few cases was the trajectory of the V2 modified from the ground after it had been fired. . . . Its only merit compared with the V1 was that it could not be shot down *en route*." He added that to devote effort to V1 could be justified if ordinary bombing, for some reason or other, had to be ruled out and stated that in the three month's campaign until the V1 sites were overrun the warheads of all the flying bombs crossing the coast weighed less than 6,000 tons, and only about half reached London. The warheads of all the V2's which reached this country over a period of seven months amounted to only 1,000 tons, and again only about half reached London. Lord Cherwell contrasted these weapons with a single R.A.F. raid with 5,000 tons of bombs, of which half fell well within one mile of the aiming point.

The remainder of Lord Cherwell's remarks were concerned with the relative ease with which the attacked might jam any form of radio control by the attacker of such missiles and with an appreciation of the work and enterprise of the scientific departments concerned. His peroration included the words: "Unless and until, therefore, our safety can be absolutely guaranteed by some international organisation, we must insist that we keep not only abreast of but ahead of any nation which might conceivably attack us in every scientific and technical device. No effort is too great to ensure this, and no effort will be spared."

These exchanges in the House of Lords are of considerable importance and they have been summarised at length in order to attempt to convey to the reader the same impression as a perusal of the full report would give. Naturally a Government representative preserves a discreet form of utterance, and, in some subjects at any rate, the questioner cannot expect more than the conventional "His Majesty's Government has this matter under the closest consideration." But straws will show which way the wind blows. There are few who would care to challenge the Paymaster General on a point of purely scientific policy: there will be equally few who feel quite the same satisfaction as he apparently does at the prospect of our being able to win any future war that may arise. His discussion of the performance of V1's and V2's as they now exist cannot be challenged: there is, however, room for misgivings at the prospect of future development of these weapons. These were shown to be relatively inefficient as destroyers of assigned targets, but there was a marked absence from the discussion of any reference to their effectiveness as psychological weapons, and in this respect, it must be admitted, they came remarkably near to achieving their purpose. There will be many, who, while they are normally out of sympathy with some of the views expressed by the two noble lords who started these discussions, will feel that what is needed is to prevent future wars, at the same time doing the best possible to win them if the calamity should once more descend upon us. They will feel that the Government certainly ought to "take the initiative in proposing . . . a permanent inter-allied Committee of Scientists" . . . and that the assurance of full control of scientific work must be fully implemented. They will feel too that the problem of the future of "directed missiles" is not whether we can use them in a future war, but whether they will ever be manufactured for use against us. They will derive little satisfaction from the reflection that if normal bombing remains possible we can unload on the enemy a greater weight of bombs in one raid than the fifty per cent of 6,000 tons of flying-bomb warheads that exploded in London in three months. These figures may change: the aim should be nothing less than to keep the figure of directed missiles landing on this country down to zero permanently, and the first step is by political action, the suggested international inspectorate being one way.

This proposal must be understood in general terms. There is of course a difference between pure and applied science: the original discovery is, as it were, ethically neutral, and only the applications good or bad. This fact will make inspection and control much more difficult, and it is certain that the committee of scientists who are to advise on the problem, will consider it with these obvious facts in mind. Their job is to find the most sensitive spot in the machinery of scientific rearmament and to throw the spanner in just there, as well as always keeping one jump ahead of the most ingenious attempts to circumvent control. The public will in fact insist that nothing should be left to chance, and would be aroused to the strongest opposition if it should turn out that any of the assurances which have been given are merely the polite form of parliamentary evasion which has often been used in the past to fob off a too insistent questioner.

How Penicillin Acts

THE development of drugs of the sulphonamide (M & B) type and, more recently, penicillin has shown that infections due to many different types of bacteria can be effectively treated by means of chemical agents. The great practical value of these substances has tended to obscure the fact that comparatively little is known of the way in which they act. The results of recent research have called for a drastic revision of current ideas on this important subject.

In spite of considerable evidence to the contrary penicillin has been regarded, until quite recently, as essentially a bacteriostatic agent. By this is meant a substance which prevents the multiplication of bacteria but does not kill them. It was supposed that penicillin owed its therapeutic properties to its power of preventing the spread of a bacterial infection, bacteria already present being dealt with by the natural defences of the body. This theory was based on the original observations of the Oxford penicillin team. They found that penicillin had

no effect on the rate of respiration of resting cultures of staphylococci (bacteria which are a common cause of septic infection). This observation was perfectly correct; the deduction made from it was that penicillin had no bactericidal effect, since if the bacteria were killed by the drug their respiration would immediately cease.

Since those observations were made however a number of other workers have reported a different effect, finding that bacteria sensitive to penicillin are killed by it in a few hours. This is in accordance with the original observations made by Fleming, who stated that bacteria growing in nutrient broth were killed by penicillin. He also found that at the same time the bacteria were broken down, or "lysed", so that the broth cultures, instead of having a cloudy appearance because of the presence of living or dead bacteria, became perfectly clear.

It has now been established that both these observations, at first sight irreconcileable, are correct. Penicillin can have two distinct effects on bacteria. Bacteria which are not actively growing are resistant to the action of penicillin. Under conditions favourable to bacterial growth, however, penicillin has the bactericidal and lytic action described by Fleming and other workers. When penicillin is added to a growing staphylococcal culture there is at first a rapid increase in metabolism, though there is no further increase in the number of organisms, and then a steady decrease until more than 99% of the bacteria are killed. It appears that even under the most favourable conditions however a few bacteria, perhaps one in a million, survive the action of penicillin; for these the name "persisters" has been given.

The discovery of the existence of these persisters has led to the suggestion that penicillin treatment should be intermittent rather than continuous. The idea behind this is that the persisters are resistant to penicillin because they are dormant forms; if treatment is interrupted they might be encouraged to start multiplying and so enter the growing phase in which they are killed by penicillin. There is however little evidence that penicillin prevents bacteria passing from the resistant resting stage to the sensitive growth phase; it is therefore doubtful on theoretical grounds whether intermittent treatment will prove more satisfactory than the continuous treatment now in general use.

The bactericidal activity of penicillin is very great; 1/50,000,000 gram is sufficient to kill and lyse 200 million bacteria. This strongly suggests that penicillin acts by interfering with the action of enzymes.

An interesting antagonism has been shown to exist between penicillin and helvolic acid, another antibacterial mould product. The latter is a true bacteriostatic agent. At a dilution of 1:30,000 it is almost entirely without effect on the respiration of bacteria in the resting stage and it also prevents the multiplication of bacteria under conditions otherwise favourable to their growth. In the presence of helvolic acid the bactericidal action of penicillin is prevented provided that both substances are added to a growing bacterial culture at the same time. This is further evidence that penicillin acts only under conditions in which bacteria are potentially capable of multiplying. If however the penicillin has been in contact with the bacteria for thirty minutes or more before the helvolic acid is added the latter then does not prevent the killing action of penicillin. From this it is deduced that penicillin does not become effective instantaneously but only after a short induction period.

The action of sulphonamide drugs is somewhat similar to that of penicillin, killing bacteria under conditions favourable to growth but not in the resting stage. Unlike penicillin however they do not kill bacteria before the latter multiply. In the presence of sulphonamides bacteria divide two or three times before the killing effect becomes apparent. This action was in fact demonstrated by workers at Utrecht as long ago as 1939 but these important results have hitherto been almost entirely ignored, probably because they were published at a time when the interchange of journals was interrupted by the war. Since the sulphonamides attack bacteria only after they have undergone two or three divisions these drugs would not be expected to interfere with the action of penicillin, which prevents multiplication. Experiment shows that this is in fact the case; indeed penicillin appears to promote the action of sulphonamides.

These results are of obvious importance both in relation to the clinical use of existing chemotherapeutic agents and in guiding the search for new ones. It is very likely that conditions occur in the body in which infecting bacteria enter a resting phase. It is therefore important that attention should be paid to the factors e.g. the action of local antiseptics, which may give rise to such conditions, since they will interfere with the action of penicillin.

The final test of any chemotherapeutic agent must be its power of overcoming bacterial infections in living animals but a great deal of preliminary research must be before this crucial stage is reached. In accordance with previous views of the action of penicillin the search has in the past been directed particularly towards bacteriostatic substances. Bactericidal substances were often regarded as being general protoplasmic poisons whose toxicity towards bacteria can be expected to be comparable with that towards animal tissue and therefore unlikely to be suitable for clinical use. It now seems that the most promising therapeutic agents will be found among those which can kill bacteria and not merely prevent their multiplication. In this respect it is perhaps significant that helvolic acid, probably the most powerful bacteriostatic agent known, gives very little protection to experimental animals infected with lethal doses of bacteria such as staphylococci, though it does give a very definite prolongation of life. It will in future be necessary to determine the effect of proposed chemotherapeutic substances on bacteria in both the resting and growing phases since it is clear that there is an important distinction between the two.

Small differences between resting and growing bacteria e.g. in their reaction to ultra-violet radiation, have been previously noted but the fundamental importance of these differences is only now becoming apparent. Investigation of the underlying causes can be expected to throw light on immunological, metabolic and many other bacteriological problems.

Spraying Metals

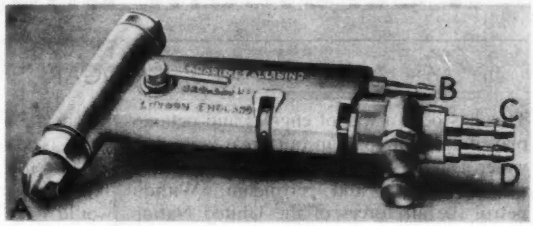
A RUSSIAN film dealing with various scientific topics in a popular manner has been circulating in Britain and it includes some shots showing the spraying of worn metal parts in order to fill out the worn areas so that subsequently

they could be machined to the correct shape. One comment was, "I should have thought it would look all right but not be very strong." This is just the sort of question which metallurgists have been considering ever since the process was first invented, by a German named Schoop, in 1910. Progress in this country was relatively slow due mainly to the effects of the last war, but by the early 1920's the method had come into very general use, not only for the sort of purpose illustrated in the film, but for many others, as for instance the deposition of protective coatings on metal surfaces liable to corrosion. Unfortunately the exact mechanism by which the coating arrived on the surface to be protected and the reasons why it adhered, together with its physical properties, received less attention than they merited, the published literature dealing mainly with new devices of various types for producing the sprayed coating.

The method is simple enough to describe. A wire of the metal to be deposited is fed into a flame where it melts and an air blast breaks up the molten metal into a fine spray and carries it to the surface to be coated; in an alternative process the metal is used in the form of a powder. The whole device is made up into the form of a "pistol" which is played, like the spray gun used with paint, over the surface to be coated. One of the few classical papers on the physical factors involved was written as long ago as 1924 by T. H. Turner and W. E. Ballard. They found that the layer was of a slightly lower density than the normal metal, due to the fact that it contained a large number of fine pores; the hardness approximated to that of the normal metal, and its strength was usually lower, though not by so much that solid masses of metal built up by spraying could not be machined. The layer exhibited a certain tendency to chip when attacked with a chisel in a direction related to the direction of spraying, but in other directions it was normal.

One problem concerned the adhesion of the sprayed layer to the base. Adhesion proved best when the base was roughened by sandblasting before being sprayed, and it was thought that the first particles might be trapped in surface irregularities, since there did not seem to be any considerable degree of alloying between the coating and the base. Even now this particular question does not seem to have been completely cleared up. A second interesting point is that, contrary to what might be expected, the spray is not particularly hot; metal may be sprayed on to a sheet of paper without scorching it.

These problems have been further discussed in a recent paper by W. E. Ballard in the *Proceedings of the Physical Society* (March, 1945). It appears that the finely divided metal is liquid at the instant of striking the surface, although this may be accounted for, not by supposing that the particles are necessarily liquid during their flight through the air, but that some of them become liquid through the liberation of kinetic energy in the form of heat when they are suddenly arrested by striking the surface. When sprayed on to glass, the particles show characteristic splash formations indicating their liquid nature, and it is stated



THE Schori metal-spraying pistol. This type operates with finely divided metal powders, and can also be used to apply coatings of synthetic rubbers like Thiokol and plastics such as Polythene, as well as glass and enamel. Powder is sucked into the pistol B; C is the intake for air at 40-45 lb. per square inch, and acetylene and oxygen are taken in through D. At the nozzle A the powder is driven out through a zone of burning gases. The technique of "metallisation" works with nearly all substances that soften when they are heated.

that studies with high speed cine cameras make it clear that the final solidified formation is due to a process occupying several stages. First the drop splashes; then, before the drop has had time to cool and solidify, the surface tension of the molten metal causes the drop to retract, and final solidification takes place with the metal particle either in the form of a central blob with a "serrated" edge, or in the form of a large blob surrounded by a ring of tiny droplets.

These "liquid" droplets are responsible for the main part of the sprayed layer, but there are in addition a relatively small number of tiny solid particles, most of which bounce off, but a few of which are trapped in the layer and can be seen as tiny solid particles.

If the pistol is held at a fair distance from the surface being coated most of the particles will have time to cool to a state of plasticity before hitting it, and the coating will present a different appearance, namely that of a number of layers of tiny spheres deformed by their impact on the surface.

On the basis of these considerations, Ballard puts forward his view of the adhesion of the layer to a surface which has been prepared by sand- or shot-blasting. He considers that the adhesion is due to the retraction of the liquid drops round the minute irregularities of the surface only, and quotes in support of this the behaviour on a smooth surface such as glass, where the retraction takes place all over the surface and produces poor adhesion, and also the behaviour on smooth surfaces, such as screw threads, where there are irregularities whose scale is larger than that of the drops, so that again adhesion is poor.

The use of the high speed cine camera in this case has produced most valuable results, and in addition to the data quoted on the physical structure of the layer has also shown that the metal spray is subject to rapid oscillations in a time of about 1/300th of a second, a feature which may be of great importance in affecting the results achieved by the process.

Petroleum and its By-products

J. L. EDGAR, Ph.D., F.R.I.C., D.I.C.

THIS has been a war of engines and octanes. But octanes played only one part in our great war effort, and a much wider generalisation would be to say that this has been a war of engines and petroleum. Without high-octane petrol the air forces of the United Nations would have been grounded, but this is also true of other petroleum products; without high-grade lubricating oils planes could never be flown and the wheels of the machines which make the planes could not be kept in motion; without bitumen and road oils the great airfields could not be constructed. Without petroleum gases the United States' tremendous programme for the manufacture of synthetic rubber would have been impossible; indeed, without petroleum and its products the whole war would have come to a standstill.

But there is another and little known aspect of the petroleum industry. To-day this great industry, which was born less than 100 years ago—to be exact, it was in 1859 that the first oil well was drilled by Drake in America—is in very much the same position as the coal industry was two decades ago. In 1813 William Murdoch introduced the use of coal gas for domestic purposes and for street lighting, and so he founded the coal-gas industry. In those early days the production of gas by the high temperature distillation of coal was handicapped by the production at the same time of an unwanted by-product, a sticky, tarry liquid which could only be disposed of by burning it as fuel. For many years now this coal tar has been the most important product of the industry; it is one of the chief sources of benzene and toluene, and from it are produced great quantities of most valuable synthetic dyes, perfumes, explosives, medicinal drugs and fine chemicals. To-day coal itself can be converted into oil and petrol by means of the process of hydrogenation; this process, which is explained diagrammatically in Fig. 1, has been developed in this country by the great skill of the technicians of Imperial Chemical Industries. Part of this firm's plant which is in operation at Billingham is shown in Fig. 2 (the big vessel seen in the centre of the photograph is the converter shown in Fig. 1.) Some of the multitudinous variety of products which may be obtained by the hydrogenation of coal are shown in Fig. 3.

And to-day we find an analogous situation in the petroleum industry; substances which used to be regarded merely as waste products suitable only for burning as fuel are now most important by-products and are as valuable as their parent products. Indeed, one of the most important synthetic rubbers is manufactured from a gas which used to be regarded as a waste product obtained during the high temperature decomposition—the so-called "cracking"—of low-grade petroleum products which is a process in common use for the production of high-grade petrol; this process has now become so important that plants are operated specifically for the production of this gas, butadiene, from which the Buna rubbers are manufactured, and the petrol is obtained as a by-product. As in the coal industry, so in the petroleum industry does hydrogenation play an important part and by the use of this process high-grade aviation petrol may be made from otherwise useless products. But more of this later; in order to get a clear picture of the by-products of petroleum it is first of all necessary to give a brief sketch of the main products themselves.

Two Types of Petroleum

Very broadly speaking, crude oils—the raw petroleum as it comes from the well—may be divided into two types, the *paraffinous* type which contain paraffin wax but little or no asphaltic matter, and the non-paraffinous or *naphthenic* type which contain little or no wax but much asphaltic matter. (There are, of course, other types, including mixtures of these two, but this simple subdivision serves as a broad basis of classification.) In all cases, however, the crude oil consists of a most complex mixture of saturated hydrocarbons varying from the simplest member of the series, methane (the chemical formula of which is CH_4), to highly complex molecules containing hundreds of atoms the formulae of which are unknown. The simplest members are gaseous and they have the following formulae and boiling points:

	Chemical Formula	*Boiling Point*
Methane	CH_4	−161·5°C
Ethane	C_2H_6	− 88·5°C
Propane	C_3H_8	− 42·2°C
Butane (normal)	C_4H_{10}	− 0·5°C

These saturated hydrocarbons all have the general formula $C_nH_{(2n+2)}$; they occur as natural gas and at one time they were burnt only as fuel or were run by pipe-line to towns and cities where they provided the chief source of fuel for heating, lighting, and other domestic uses; the heavier gases, propane and butane, were "bottled" by compressing them at high pressure into steel cylinders or bottles, and they could then be used as most valuable portable sources of fuel for outlying districts far from any normal source of gas or electricity. But to-day these gases are no longer a mere by-product of the petroleum industry suitable only for burning; now, as will be described later, they form the basis of a great new synthetic chemical industry.

The natural gases are separated from the crude oil at the field itself; the gas as it issues from the well also contains some of the heavier vapours, which would be very valuable in the light petrol, and it is said to be "wet". In addition to this, the lightest petrol itself contains some of the heavier gases such as propane and butane, and it is said to be "raw". The heavier vapours are therefore removed from the gas by an absorption process, a stabilising plant such as is shown in Fig. 4 being used for this purpose. The "wet" gas is passed up the stabilising towers down which passes a stream of light gas oil. This serves both to remove the propane and the butane

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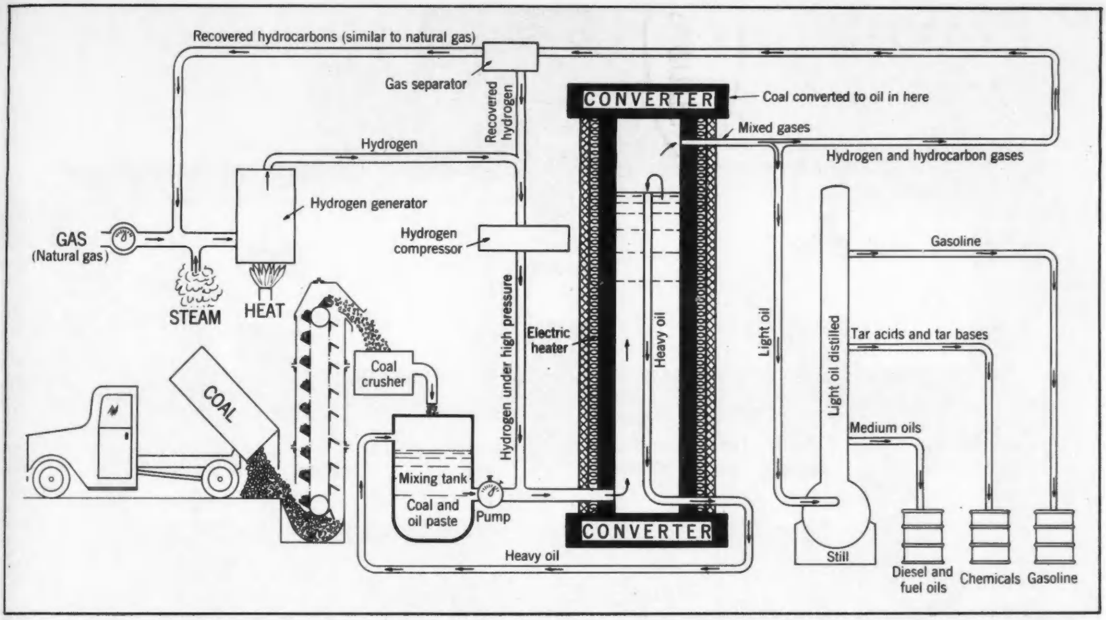


FIG. 1 (*above*).—Simplified flow sheet for the hydrogenation process used for the conversion of coal to oil and petrol. (*By courtesy of the U.S. Bureau of Mines*). FIG. 2 (*below*).—Part of the coal hydrogenation plant at Billingham.

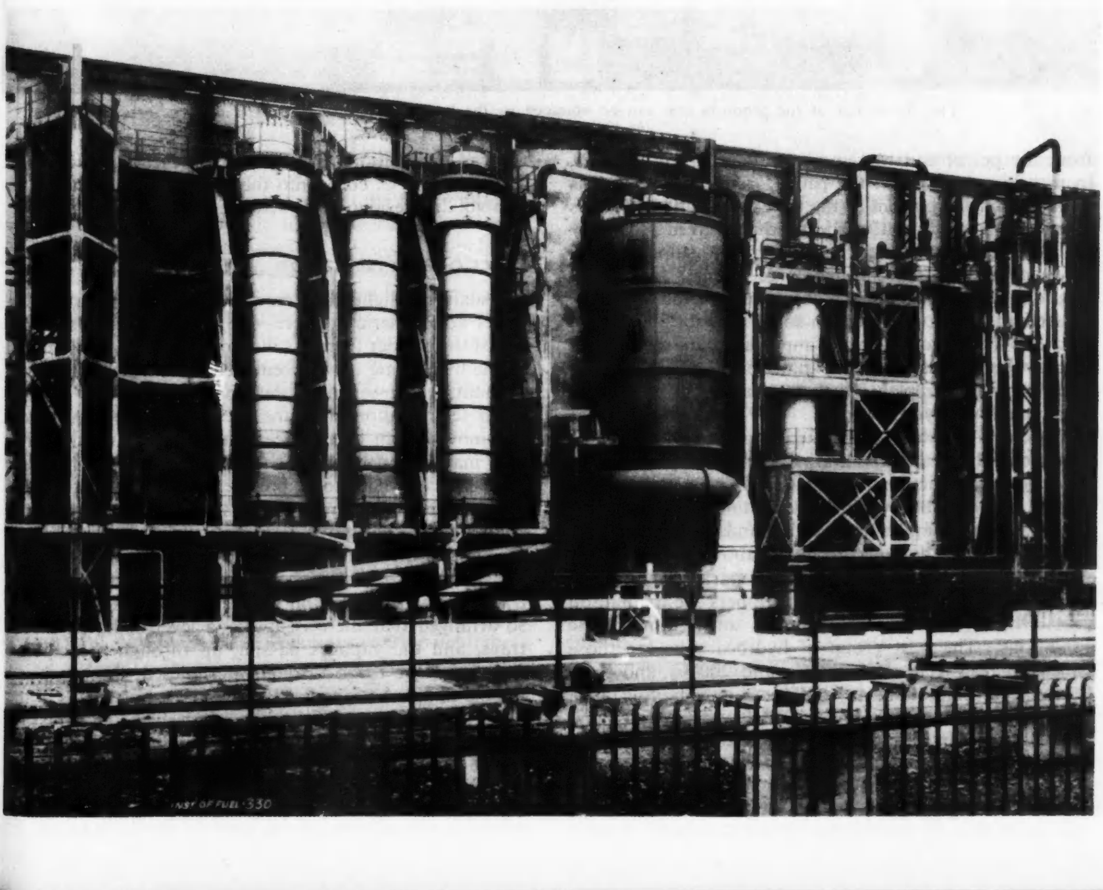


FIG. 3.—A few of the products that can be obtained by the hydrogenation of coal. (*By courtesy of the U.S. Bureau of Mines.*)

from the petrol and to remove the vapours in the gas, these being absorbed in the petrol. The "rich" petrol is run off from the bottom of the towers, and the dry gas is taken from the top; it is scrubbed and freed from any undesirable impurities such as hydrogen sulphide, and it is then distributed through large mains. A valuable by-product obtained in this separation process is the gas helium, which is present in some, but not all, natural gas; this is of considerable importance in the United States, where it is used for the filling of dirigibles in which it has completely replaced the more dangerous and highly inflammable gas hydrogen.

The crude oil itself is separated into the various "cuts" which constitute the well-known petroleum products by the process of fractional distillation. The boiling points of the hydrocarbons which constitute petroleum all increase as their molecular weights and their complexity increases, as will be noted from the above table, and the various grades of petroleum can be separated by making use of this gradation; the lowest members are the natural gases which separate out themselves under atmospheric conditions. The next group of hydrocarbons are those which boil between about 10° C., and 200° C., and these form the petrol fractions or "cut"; next in the boiling range come kerosene and the "white spirits" (or naphthas) and these consist of hydrocarbons boiling between about 150° C. and 300° C., and, as in all these cuts, it will be noted that the petrol and kerosene fractions overlap; the hydrocarbons boiling between 250° C. and 380° C. constitute the gas oil fraction, and those hydrocarbons which boil at above 350° C. come into the lubricating oil fraction, a non-volatile residue being left.

Fractional Distillation

Usually the light fractions are removed by a distillation under atmospheric pressure—the crude oil is "topped"—whilst the heavier fractions, i.e. some of the gas oil and all of the lubricating oil, are removed by a distillation under vacuum; at lower pressures the hydrocarbons boil at lower temperatures since the pressure of the atmosphere is removed from the surface of the liquid, and therefore they may be separated more easily. The crude oil is first heated in a furnace to a predetermined temperature and the oil-vapour mixture then passes into a fractionating column; this consists of a large vertical cylindrical vessel throughout the length of which there are trays which have in them holes over which are fixed caps. These are the fractionating trays and on them are fitted weirs which are so arranged that there is always a level of liquid in the trays, and the vapours passing up through the column therefore have to go through the holes in the trays and bubble under the caps fixed above these holes; this is the usual method adopted in industry for separating a mixture of components whose boiling points differ by fractionation.

The degree of fractionation in the fractionating column is controlled by a special method known technically as "reflux". Part of the condensed liquid which is

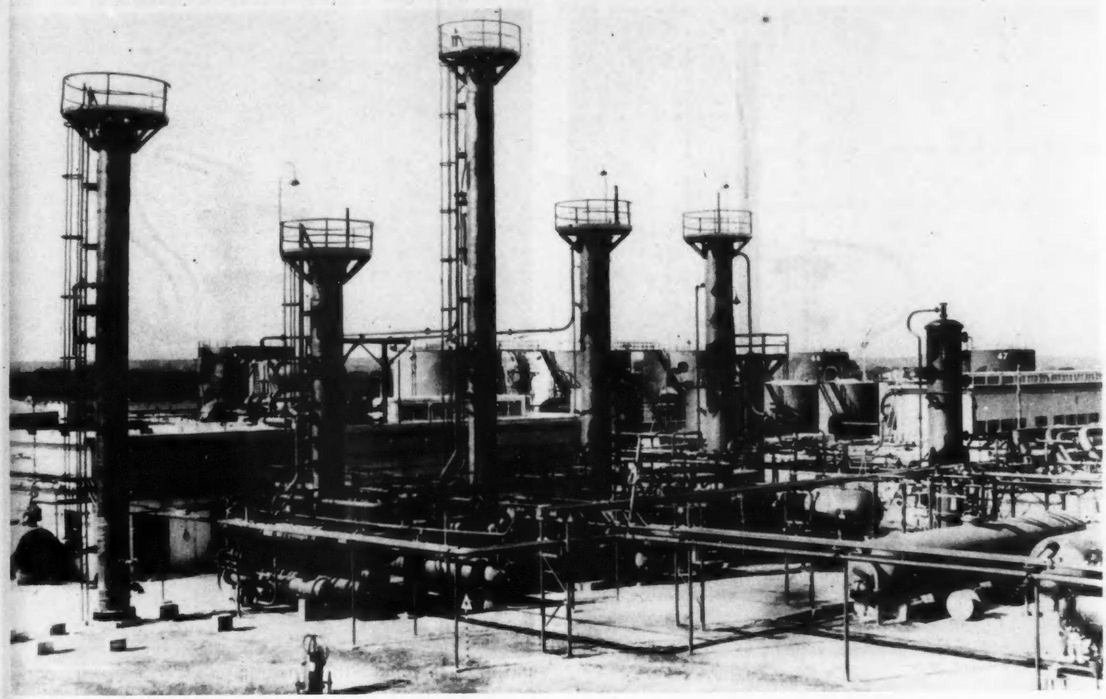


FIG. 4.—A stabilising plant used to recover propane and butane from raw petroleum. (*By courtesy of Foster Wheeler Ltd.*)

drawn off from various sections of the column is returned, or "refluxed," back into the column, the amount being automatically controlled so as to keep the temperature at any one point constant; if the temperature, which is highest at the bottom and lowest at the top of the column, increases, then more cold liquid is returned so as to bring it down, and vice versa. Thus the lightest boiling fractions rise to the top of the column from which they are drawn off, the residue is drawn off from the bottom of the column, and at intermediate points in the column intermediate fractions may be removed. In a crude oil distillation petrol is removed from the top of the column; the residue for a second vacuum distillation may be taken from the bottom, whilst kerosene, white spirit, and gas oil may be taken as "side cuts" from intermediate points. Similarly, in a vacuum distillation of a topped crude the products would be gas oil, lubricating oil fractions, and a residue, whilst in order to split up the lubricating oil fractions these may be given yet another vacuum distillation to yield a further small quantity of gas oil, spindle oil, light machine oil, heavy machine oil and cylinder oil, plus the residue. Again the overlap in all these processes should be noted, gas oil being obtained in each distillation.

A modern single-stage atmospheric distillation plant is shown in Fig. 5; this particular unit is capable of handling 1500 tons of crude oil per day, producing petrol, solvent naphtha, white spirit, kerosene, gas oil, and a residue. The crude oil is heated in the heater on the left of the photograph; it then passes into the fractionating column seen in the centre. This is under atmospheric pressure, and in it the separation of the crude into its various components takes place; the points from which the fractions are withdrawn from the column are indicated by the valves and platforms on the left-hand side of the column. The vapour leaves the top of the column via the big pipe, and the condenser and heat exchange equipment in which these vapours are condensed to liquid are clearly seen.

Fig. 6 shows a single-stage vacuum distillation plant which is capable of handling 400 tons of crude oil daily; from this is produced gas oil, light lubricating oil, heavy lubricating oil, and a residue which may or may not be asphalt according to the type of crude oil that is being processed. This plant is typical of the many vacuum distillation units in use for the manufacture of bitumen. The fractionating tower and condenser equipment are seen in the centre of the photograph, but the heater is hidden by the pump-house (the building in the foreground).

The processes of atmospheric and vacuum distillation may be incorporated in one plant, the residue from the bottom of the column of the atmospheric fractionating tower being taken through a second heater and then into a vacuum fractionating tower. Such a unit is illustrated in Fig. 7. This particular plant is capable of handling 300 tons of crude oil per day; under the atmospheric stage it produces light and heavy petrol, light and heavy white spirit, and a light gas oil; the residue passes to the vacuum stage in which is produced a heavy gas oil, a wax distillate

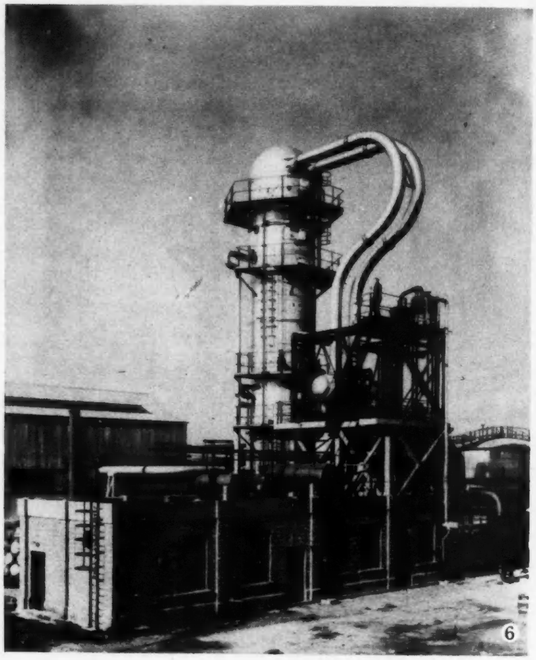
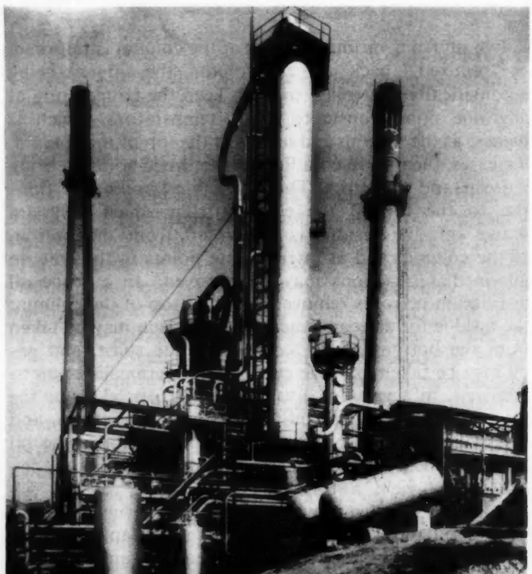


FIG. 5.—A single stage atmospheric distillation plant used for topping crude oil. FIG. 6.—Single stage vacuum distillation plant for processing a topped crude. FIG. 7.—Two stage distillation plant capable of handling 300 tons of crude oil a day. FIG. 8.—Two stage distillation plant with a capacity of 850 tons of crude oil per day. (*These four photographs are reproduced by courtesy of Foster Wheeler Ltd.*).



(for the production of paraffin wax), a heavy paraffinic lubricating oil, and an asphalt residue. The heater is on the right-hand side of the photograph, the vacuum column is in the centre foreground, and the atmospheric column is in the centre background. The similarity between these two columns and those pictured in Figs. 5 and 6 will be noted.

Distillation in Two Stages

A much larger two-stage atmospheric- and vacuum-distillation plant is shown in Fig. 8 in which the two columns in the centre of the photograph will be noted; the small column which is seen between the atmospheric column (centre foreground) and the stack is a stabilising column similar to those shown in Fig. 4. This plant is capable of handling 850 tons of crude oil per day; under the atmospheric stage it produces petrol, white spirit, kerosene, and light gas oil, whilst under the vacuum stage it produces heavy gas oil and three lubricating oil cuts (spindle, machine, and cylinder oils), and leaves a residue of asphalt.

The principle of the two-stage distillation plant is shown diagrammatically in Fig. 9. The vapours leaving the top of the column are very hot, and they are therefore made to give up some of this heat to the crude oil going into the plant before the crude enters the heater; this is done in heat exchangers which, from a point of view of economy in fuel consumption and waste heat recovery, form a very important part of the equipment of the plant; the bottom products from the vacuum tower are also heat-exchanged with the crude. The reflux lines discussed above will be noted, the amount of reflux going back into the column being automatically controlled by the temperature at the top of the column.

If the crude is of the asphaltic type then the lubricating oil fraction is obtained by direct distillation and the asphalt is left as a residue; the very important uses of asphalts and bitumens are too well known to require discussion here. The lubricating oil fraction thus obtained is almost free from the very undesirable asphaltenes and, if it has not been already split up on the original distillation plant, it may be given a further fractional distillation under vacuum in order to separate it into the spindle, light machine, heavy machine, and cylinder oils mentioned above—distillation is by far the least expensive method of refining lubricating oil. There is only a very small market for the residue which is left and it is usually pumped away, blended with a light oil, and then burnt as fuel. The lubricating oils which are thus obtained have now to be further refined; this may be done by either giving them a treatment with concentrated sulphuric acid, or by extracting them with special solvents—when the solvent extraction method is used this is usually done before the distillation process. Treating with sulphuric acid may either be done in large agitators in which the acid and oil are thoroughly mixed by blowing with air and the sludge is allowed to settle out under the force of gravity over a period of 12 to 24 hours, or it may be done in a small acid contacting tank when the sludge produced is separated out immediately by means of very powerful centrifuges. The amount of acid that is used depends entirely on the grade of oil being refined, and all the unwanted impurities

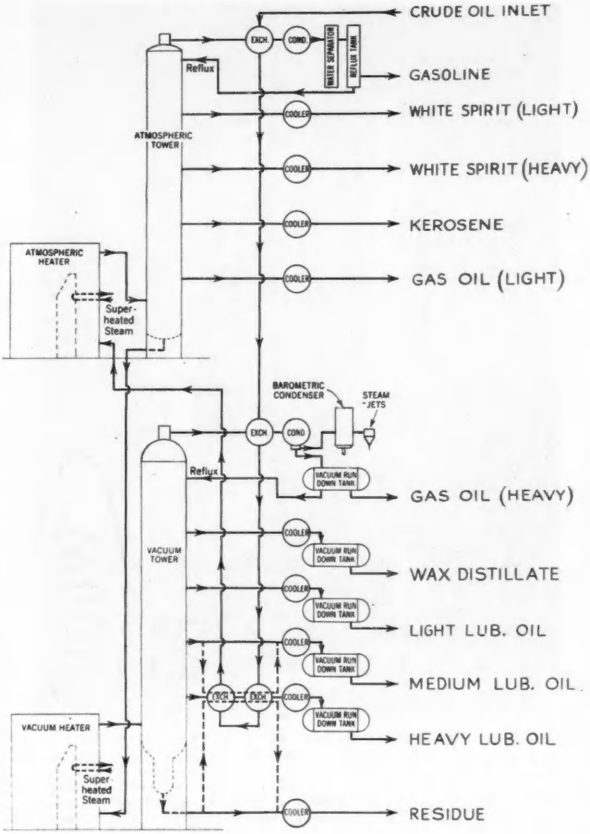


FIG. 9.—Simplified flow sheet for a two stage distillation plant

are thrown out of the oil in the form of a thick, heavy, black sludge which is removed by either of the above methods. The last traces of sludge and any other impurities which might discolour the oil or make it unstable are removed by giving it a treatment with a small quantity of activated earth at a high temperature and then finally filtering it. Small amounts of the spent earth thus obtained after filtration find an outlet as fillers in some plastics, but the bulk of it has to be dumped.

Solvent Extraction

In the case of the paraffinic crudes, the crude oil is topped to give the light petrol, kerosene, and gas oil fractions as with the asphaltic crude; the lubricating oil fraction may be taken at the same time or it may be obtained by a second distillation, but the oils cannot be freed from paraffin wax (which may be regarded as an impurity in the same way that the asphalt could be regarded as an impurity in the naphthenic lubricating oils) by distillation because the wax is volatile at high temperatures. With these types of oil the impurities must be removed by a process known as "solvent extraction"; the impurities, but not the wax, are dissolved out of the oil

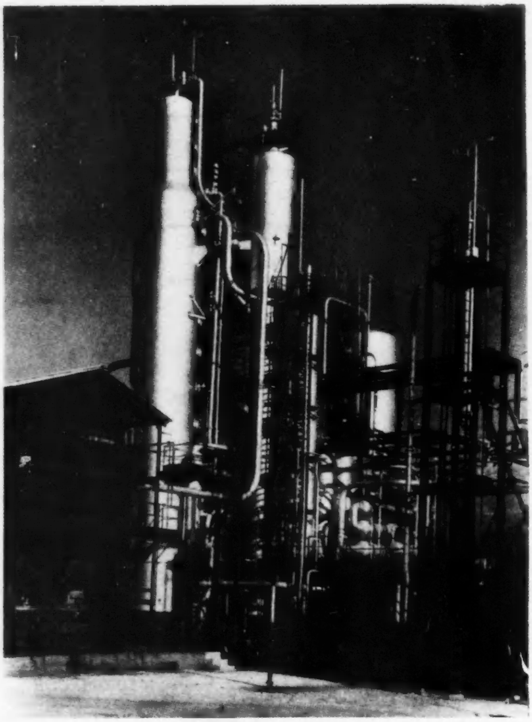


FIG. 10.—Plant for the furfural extraction of lubricating oils. (*By courtesy of the Lummus Company*).

with special selective solvents which remove only the unwanted matter and do not affect the oil. The wax is separated out by precipitating it with a second solvent which dissolves the oil but not the wax, which is then filtered off; in some plants using special solvents these two processes may take place in one operation.

A typical solvent extraction plant is shown in Fig. 10. This particular plant utilises furfural (a chemical which is manufactured on a large scale in America from oats), as the selective solvent, and it is capable of extracting about 700 tons of oil daily. After it has been extracted with furfural, the oil next passes to the solvent de-waxing plant in which it is mixed with a blend of acetone and benzole; this mixture is chilled down to a temperature of about −15° F., at which temperature most of the wax is thrown out of solution and is then filtered off. These solvent extraction plants usually consist of three sections—an extraction system in which the crude oil is washed in counter-current flow with the solvent, a system for the recovery of solvent from the extracted oil, and a system for the recovery of solvent from the residue which has been extracted. The question of efficient solvent recovery, which is invariably done by a distillation method very similar to those described above, is most important in view of the high cost of the solvents used (furfural, for instance, costs over £100 per ton).

After the oil has been extracted and de-waxed it is given a light refining with a small quantity of activated earth in order to improve its colour and to render it more stable. The oil and earth are mixed in large agitators from which the mixture is fed through an oil-fired heater and then into a second agitator in which the oil and earth are thoroughly mixed by shaking them up with steam at a temperature of over 200° C. for about an hour; this mixture is then cooled to about 150° C. and it is fed to large filters which remove the earth. The finished oil is then ready for marketing, or it may finally be split into light, medium, and heavy components by means of a fractional distillation.

The whole refining process may be represented by the scheme shown in Fig. 11. The petrol, kerosene and white spirits also have to be refined before they are marketed; they are given a treatment with sulphuric acid and with an activated earth in exactly the same way as is done with the lubricating oils, except that it may be necessary to give them further treatments with special chemicals in order to improve their general properties and render them more stable; the refining of these grades is not included in Fig. 11 which is intended to illustrate the differences in treatment of the two types of crude oil.

This shows very briefly how the various petroleum products are obtained from the crude oil, but the second purpose of this article is to discuss the various by-products that are obtained on the way. By far the most important source of these by-products is natural gas and the lighter fractions of the petrol cut, together with the gases obtained by the "cracking" process discussed below; but first let us deal with those products obtained during normal refinery operations.

The light fractions of the naphthenic crudes, especially the gas oil cut, contain appreciable quantities of easily extractible naphthenic acids, and these find wide applications in the paint and varnish industry as emulsifiers and

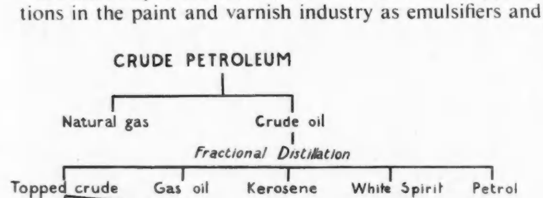
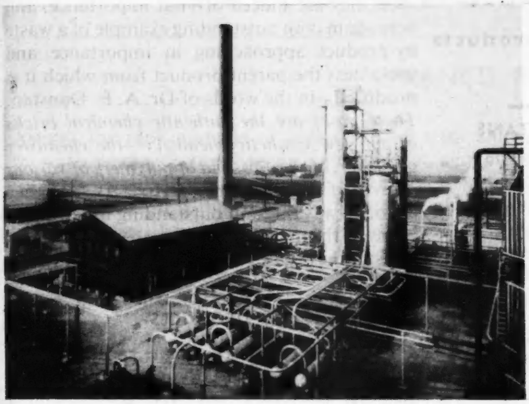


FIG. 11



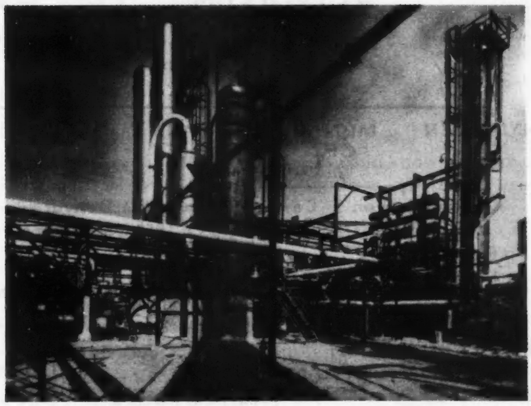


FIG. 12 (*left*).—View of a cracking plant. FIG. 13 (*above*) Reactors and fractionating columns of a catalytic cracking plant. (*Both photographs by courtesy of the Lummus Company*).

detergents and in many pharmaceutical preparations. The process of extraction is very simple; the gas oil is simply bubbled through a dilute solution of caustic soda with which the naphthenic acid forms sodium naphthenate; the solution is separated from the gas oil, treated with concentrated sulphuric acid, and the naphthenic acid separates out. It is washed and dried, and it is then ready for marketing.

During the actual distillation of these crudes the residue which is left is asphalt or bitumen and is, of course, of very great value and importance, so much so that it can hardly be termed a by-product although it may be regarded as such in the manufacture of lubricating oils.

Another by-product obtained during the processing of the products from these crudes is the acid sludge produced when the redistilled lubricating oils, or the light ends, are refined with sulphuric acid; usually this is burnt under the boilers as fuel, but in some refineries valuable sulphonic acids are recovered from the sludge, and these, or their sodium salts, find wide applications in industry as emulsifiers and wetting agents. In another process for the treatment of acid sludges, the sludge is treated with ammonia with the production of ammonium sulphate, valuable as an artificial fertiliser, and a product suitable for burning as fuel. In yet another process the sludge is treated for the recovery of part of the sulphuric acid as such.

In the case of paraffinic crudes by far the most important by-product is the paraffin wax, and here again in some instances, as in the case of asphalt in highly asphaltic naphthenic crudes, it is the wax that is the most important product and the lubricating oils that are the by-products. The wide and varied uses of the paraffin waxes in the electrical industry, in the production of candles, in the manufacture of matches and so on, are far too numerous and well known to be dealt with here.

In the solvent refining of lubricating oils there is obtained a highly complicated aromatic extract, and at one time this had a value only as fuel; but to-day this has a wide application as a rubber extender and as a plasticiser for various synthetic resins used in the plastics industry; it also finds wide uses in the paint industry.

Most crude oils contain, in addition to the fractions outlined above, a small proportion of aromatic substances, but until recently it was considered that their concentration was so low that their recovery was not a commercial possibility; but to-day the process of fractional distillation by which narrow boiling point fractions may be separated has reached such a degree of perfection that these low boiling products can now be separated from the light petroleum fractions, and important quantities of toluene, together with some benzene and xylenes, are now produced by these methods.

Going to the other end of the petroleum scale, an important use for the previously unwanted residues has recently been developed; by decomposing these under strictly controlled conditions at high temperatures, liquids known as olefins may be produced. These are then treated with sulphuric acid to produce what are known as alkyl sulphates, the sodium salts of which are used as synthetic soaps and detergents; the applications of these so-called ester salts are most numerous, and they have been successfully applied to industries as varied as textiles, engineering, and dairy farming.

Cracking

But now to deal with the most important source of by-products—natural gas and the gases produced in cracking operations. Only a very small proportion of the petrol in use to-day is straight-run petrol, i.e. produced by direct distillation of crude oil. By far the greater part is produced by the thermal decomposition of heavier grades of oil. This is the process known as "cracking", and the word actually describes what happens in the process—the heavier molecules in the heavy oil, usually gas oil or a low-grade residual oil, are broken down under pressure and at high temperature, sometimes with the aid of what is known as a catalyst (a neutral substance which helps to speed up the decomposition but takes no part in the reaction itself), into the lighter and smaller molecules which constitute the petrol fraction. In practice, the natural straight-run petrol is itself broken down by giving it a light cracking and "reforming" treatment when it is found that its properties, particularly its detonation

FIG. 14

properties in a standard engine—the so-called "octane number"—are greatly improved.

Figs 12–13 show three typical modern cracking plants. The gas oil, or whatever stock is being processed, is heated to the cracking temperature in the heaters seen on the left of the photographs in Figs. 12 and 13. It then passes to the reactors seen in the centre of the photographs; the products of the cracking operation, the light ends, are removed from the top of these towers and the uncracked residue is removed from the bottom, and it is fed back into the heater as "recycle stock" together with fresh feed going to the heater. These three plants are all capable of cracking about 2,000 tons of gas oil per day.

But as well as the light petrol fractions and saturated hydrocarbons the cracking operation also produces unsaturated hydrocarbon gases as a direct result of this thermal decomposition; such gases are ethylene, propylene, and the butylenes. These gases correspond to the ethane, propane, and butane occurring in natural gas, the difference between the two series being that the unsaturated gases are, as their name implies, not fully saturated with hydrogen; they all have two hydrogen atoms less than their saturated brothers, and they have the general formula C_nH_{2n} instead of $C_nH_{(2n+2)}$.

To-day these gases can no longer be regarded as waste products of the cracking process, simply to be burnt as fuel; they are indeed of vital importance, and here again is an outstanding example of a waste by-product approaching in importance and usefulness the parent product from which it is produced. In the words of Dr. A. E. Dunstan: *These gases are the authentic chemical bricks of our new synthetic chemistry—the chemistry of rubber, of plastics, and of polymers of various degrees of molecular complexity.* As such they are of great value and outstanding importance. A few of the many and varied uses and applications of these gases are summarised in Fig. 14.

Important By-products

The saturated gases ethane, propane, and butane, all of which occur in natural gas, may be converted into the corresponding unsaturated gases ethylene, propylene, and butylene (together with butadiene, a gas which is even more unsaturated, that is, even shorter of hydrogen than the parent butylene) by the process of catalytic dehydrogenation wherein the saturated molecules have two atoms of hydrogen knocked off. Some of the many products which are produced from these unsaturated hydrocarbon gases and some of the many uses to which they are put are presented in the table in Fig. 14. It will be noted that their uses vary from accelerating the ripening of fruit to the production of synthetic rubber, from the production of anaesthetics to the manufacture of explosives, from the protection of motor-car radiators against freezing to the manufacture of gramophone records.

The by-products obtainable from methane are not included in the table, but nevertheless this gas is assuming a growing importance. By treating it at high temperatures it is broken down into its parent elements, carbon black and hydrogen. Carbon black has very important uses as a filler for rubber goods (the manufacture of tyres absorbs thousands of tons) and in the production of printing inks and paints; hydrogen has a most important use in the production of synthetic ammonia which is converted into fertilisers and explosives, or which may be used in various process and as a refrigerant (e.g. in solvent dewaxing plants). The production of acetylene from petroleum has not yet attained very great commercial significance, but it is a valuable base material for the production of synthetic rubber, special plastics, and fine chemicals, and its importance is growing rapidly.

The synthetic chemical industry which has been built up around the by-products of petroleum has grown up during the last few years, and to-day it plays an absolutely vital part in the war effort of the United Nations. It may truly be said to be a war baby of its parent petroleum industry, but it is a baby which is fine and healthy and gaining weight with extreme rapidity; indeed, it bids fair to outstrip its parents in the not far distant future.

Wild Orchids of Britain

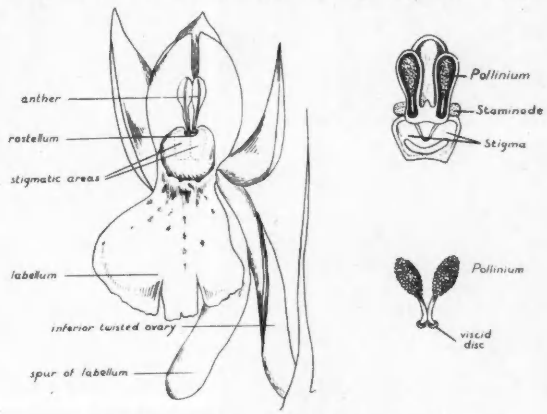
FRANCIS ROSE, B.Sc., F.L.S.

AMONG the rank and file of botanists, and even among those to whom "botany" seems a dull subject, suited best to aged, bearded gentlemen, wild orchids have a never failing appeal. It is difficult to analyse the reason for the strange fascination which the orchid race has for so many. Possibly it is partly due to the many and bizarre forms assumed by the members of the family, and to a certain delicacy and quaintness of texture possessed by few other plants.

The Orchid family (*Orchidaceae*) belongs to the great plant group known as the Monocotyledons, and is related, as one might imagine, to the irises, and more distantly to the lily family. The flowers of all orchids are characterised by remarkable modifications, designed (not always, it appears, too successfully) to facilitate insect pollination. Those of many species attract attention by their almost exact likenesses to certain insects; in fact Bee Orchis flowers are sometimes found damaged by insect attacks, male humble-bee having apparently mistaken the flowers for female bees. During such attacks pollination is likely to occur.

Of all flowering plants, the *Orchidaceae* are more highly evolved than perhaps any others in floral structure. All species are characterised by zygomorphic (bilaterally symmetrical) flowers, in which one of the three petals is enlarged and highly modified to form a *labellum*, which serves as a landing platform for insect visitors. The labellum is often spurred and the spur may contain nectar. The rest of the floral leaves, two petals and three sepals, arch over to form a more or less perfect hood to the flower. The labellum is really the upper petal, but by twisting of ovary and flower stalk it is brought into the lower position. In those few species where it is uppermost, this is due to further twisting of the flower stalk, so this position is evidently a secondary feature. The ovary is three-lobed and inferior. Primitively there are three anthers, as in the irises, but in all British species (with one exception) two anthers are reduced to mere humps or *staminodes*. The remaining anther is very strange; instead of a stalked stamen we have a projection known as the *rostellum*, above which is a short stout *column* bearing in front a pouch, or pouches, often protected by a sheathing membrane, as in the subtribe *Ophrydeae*. In these pouches are two pollen-masses or *pollinia*, club-like and stalked in the *Ophrydeae*, and egg-shaped in the *Neottideae*. The pollinia are attached by viscid discs at their base. In *Orchis* the mechanism of pollination, is as follows; an insect alighting on the labellum presses its forehead against the rostellum and so brings the viscid discs of the pollinia into contact with the top of its head. One or both of these are, as a result, removed when the insect leaves the flower. By a wonderful provision of nature, the stalks of the pollinia depress themselves in about the time likely to be required to fly to the next plant, say ten to fifteen seconds; hence when another flower is visited the pollinia are now nearly horizontal and are pushed against the fused stigmatic surfaces below the rostellum. Some pollen grains will adhere to the stigma, and the insect will then carry on to another flower and pollinate that as well. Those who are interested in knowing more of the marvels of orchid fertilisation are advised to read Darwin's fascinating book, *The Fertilisation of Orchids*.

Perhaps the second feature that strikes the man in the street most about our British orchids is the extreme rarity of so many species. This has often been supposed to be due to over-collecting, especially by non-botanists, for decorative purposes; and from the insensate way in which this is carried out, there is little doubt that species such as "Ladies' Slipper" (*Cypripedium calceolus*) have been rendered all but extinct mainly through this cause. It seems more probable, however, in the cases of most species that other factors are at work. Our rarest native species, *Epipogum aphyllum*, for instance has only been seen in four stations in Britain, and on only six occasions altogether. So the species has never, in recorded history, been plentiful enough for collectors to have the opportunity appreciably to reduce its numbers! The cases of *Orchis Simia* and *O. militaris* are rather different; these species were at one time common in certain places in the upper Thames valley and Chiltern areas, but have so decreased during the last century that now *O. Simia* is confined to one regular station, and *O. militaris* has not been seen, as far as we know, for about 30 years. Many of the stations for these species were little known and of difficult access, and in latter years they have been little interfered with by the public owing to their restricted areas of growth; even so the rapid decrease has gone on, and from the observations of the writer and others more eminent it appears almost certain that grazing by rabbits, and possibly a slight climatic change, are the principal causes of this.



Flower structure of an orchid (*a*) *Front view of flower.* (*b*) *Stigma and modified stamen.* (*c*) *The two pollinia.* (*a, after Blodwen Lloyd; b and c, after Jepson*).

Another feature of our British orchids, more important scientifically and less well known to the general public, is the extreme restriction of many species to a few localities or areas in a way at first glance unaccountable. This

BRITISH RCHII

1.. *Gymnadenia conopsea*. A specimen of the
common on chalk.

2. *Neottia Nidus-avis*. This, Bird's Nest Or
honey-coloured saprophyte humus in dark

3. *Ophrys apifera*. This pla ws the variat
Bee Orchid.

4. *Epipactis latifolia*, the Br ved Hellebor
labella which can be seen en with imit
pouches are actually quite

5. *Ophrys aranifera*, the Early Orchid, from
6. *Ophrys muscifera*, the Fly ; perhaps the
insect mimicry in the famil

7. *Orchis maculata*, the Spo chid of basic
difference between the lab his orchid an
elodes (Fig. 11).

8. *Aceras anthropophora*, the Orchid. The
similar to the closely rela *Simia*; both
coumarin; *Aceras* lacks a

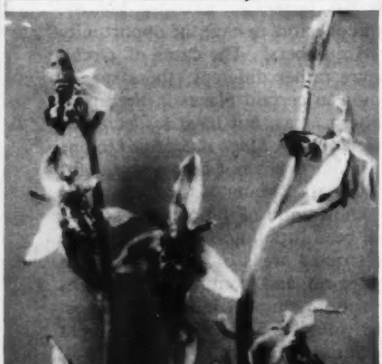
9. *Orchis Simia*, the Monkey This specime
only regular British statio fordshire, an
remarkable 5-lobed lip, and b-shaped pol
has recently been refound

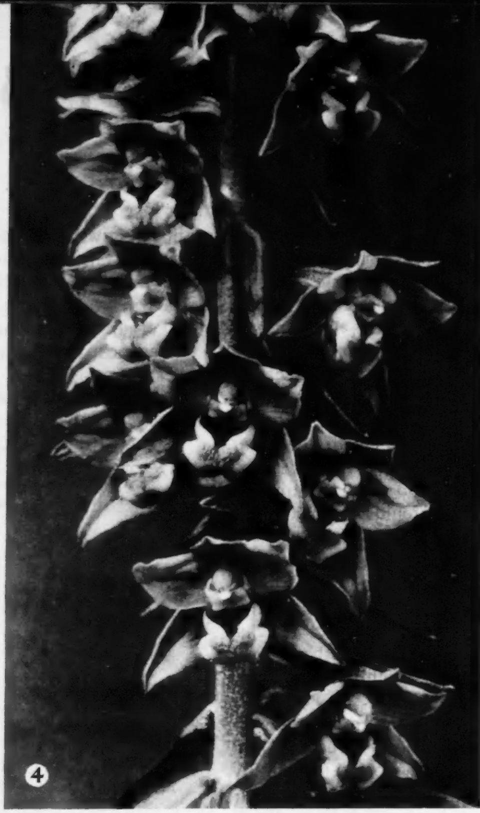
10. *Platanthera chlorantha*, t ter Butterfly.
spike, diverging pollinia, a ents basic soil
the Small Butterfly Orchid aller plant wi
denser spike, and parallel ; it often fre
though not always.

11. Albino *Orchis elodes* in a num bog. Th
well shown.

12. *Orchis morio*, the Green-v or Green-win

Photo and 9, were take
the re y W. H. Spread





[B]RITISH [O]RCHIDS

...*nopsea*. A [sp]ecimen of the Fragrant Orchid, ...alk.

...*avis*. This, [B]ird's Nest Orchid, is a wholly ...d saprophyte ...mus in dark woods.

...*a*. This pla[nt show]s the variations seen in the ...

...*lia*, the Br[oad-lea]ved Helleborine, has pouched ...an be seen ...en with imitation nectar; the ...tually quite ...

...*a*, the Early [Purple] Orchid, from a Kent downland.

...*ra*, the Fly ...; perhaps the best example of ... in the famil[y]

...*a*, the Spo[tted Or]chid of basic soils. Note the ...een the lab[ellum of th]is orchid and those of *Orchis* ...

...*ophora*, the [Man] Orchid. The flowers are very ...closely rela... *Simia*; both species contain ...*ras* lacks a s...

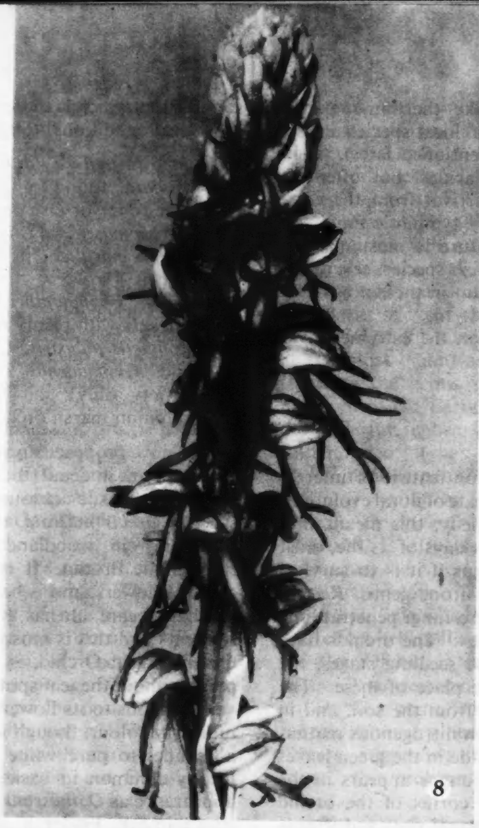
...he Monkey ... This specimen came from the ...ritish station ...fordshire, and shows well the ...obed lip, and ...b-shaped pollinia. This species ...en refound ...

...*lorantha*, t[he Grea]ter Butterfly. This has a lax ...g pollinia, a[nd frequ]ents basic soils only. *P. bifolia*, ...erfly Orchid ...aller plant with ovate leaves, a ...nd parallel ...; it often frequents acid soils, ...ays.

...*s elodes* in a ...num bog. The acid habitat is ...

... the Green-v[eined] or Green-winged) Orchid.

Photo[s] ... and 9, were taken by J. H. Lavender; the re[st by] W. H. Spreadbury.



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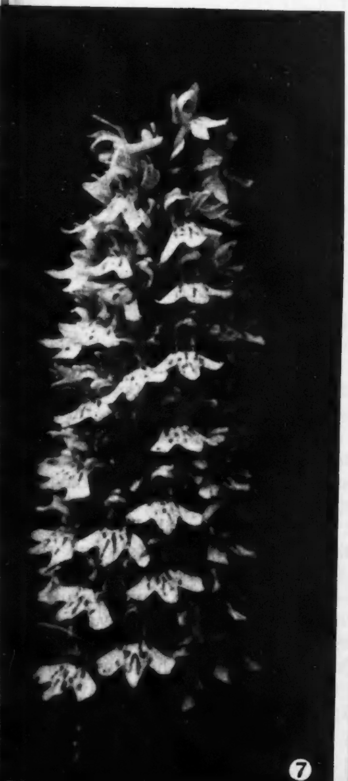

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feature is not seen to anything like the same extent on the continent, where some of our local species are so widespread (examples of this are mentioned later). It is often apparently due to soil peculiarities, but often to other factors. Such may be: late arrival from the continent; restrictedness of the necessary symbiotic fungi; or local climatic distinctions. This feature is most marked in some of our Kentish or S.E. English species, several of which are frequent and often abundant in these areas and unknown or very scarce elsewhere: it may be associated with the fact that in Britain we are in the extreme N.W. European limit of many species.

Mycorrhiza

To the biologist, however, the main feature of interest of the orchids, apart from their high state of floral evolution, is their symbiotic mode of life. Briefly, this means that every orchid plant, after the first few days of its life, must be infected with a mycorrhizic fungus if it is to survive. The fungi concerned are nearly all of one genus, *Rhizoctonia*. The threads or *hyphae* of these fungi penetrate the outer cells of the orchids' root cortex. The orchids have no root-hairs of their own after the seedling stages, the fungal threads or hyphae taking the place of these. The fungus absorbs the water and salts from the soil, and in some woodland species broken-down nitrogenous matter, receiving in return carbohydrates made in the green leaves of the orchid plant. Although the fungus appears in the microscopic sections to invade the cortex of the orchid root, the partnership is at least an equal one, and if anything favours the orchid. Indeed, in the case of our three saprophytic species which grow among decaying leaf humus, the orchids are really parasitic on the mycorrhizic fungus, as, having no green leaves, they can make no food of their own, but must receive all from the fungus. This process of symbiosis is of fairly recent discovery, and explains the difficulty, long known, of getting orchid seed to produce mature plants; germination, but no more, occurs in the absence of the right fungus.

It is of interest to note here that the terrestial orchids share many common features with other mycorrhizic groups, such as the wintergreens (*Pyrolaceae*). Both have minute wind-borne seeds consisting of a spindle-shaped envelope, with a tiny undifferentiated embryo of a few cells; and many species in both families are partial or total saprophytes living in dark woods, on decaying humus. The Birds Nest (*Monotropa*) is a case in point, living under similar conditions to the yellow, leafless orchid saprophyte *Neottia nidus-avis*, which it greatly resembles in appearance.

The irregular distribution of many orchid species is a strange phenomenon. It seems explicable, however, partly by climatic effect on the mycorrhiza and partly by the fact that many species are monocarpic, i.e. take many years to mature and then flower but once. Even those species which are regular in their appearance are often very irregular in the numbers of plants flowering. It seems probable to the writer, as a result of many observations, that certain groups of orchids may share the same species of mycorryhizic fungus, since they are so often closely associated. Since it is the fungus which lives in the soil it is this which is more likely to be affected by different ecological conditions. Such groups are as follows:

1. *Ophrys apifera*, *arachnites*, *aranifera;* and *Orchis ustulata;* found in very old grassland, on chalk or limestone; or else on sea cliffs if not on these soils.
2. *Orchis mascula*, *Listera ovata*, *Platanthera chlorantha*, *Orchis maculata;* in basic clay woodlands.
3. *Orchis purpurea*, *Aceras*, *Ophrys muscifera*, *Listera ovata*, *Cephalanthera pallens*, *Neottia;* in chalky thickets with plenty of humus.
4. *Epipactis palustris*, *Orchis incarnata*, *Liparis loeselii*, and *Gymnadenia conopsea* (large dense-flowered variety only); on fen peat. *O. praetermissa*, the common marsh orchis, is less particular.

It is now proposed to refer to some of the more interesting species in detail (though it is hard to pick and choose in a family of such consuming interest!). Our commonest species, *Orchis mascula*, the Early Purple Orchid, occurs commonly in woodlands on basic and neutral soils throughout Britain. It is a showy plant with spikes of carmine flowers, and is believed to be the "long purples" of Shakespeare. It has, however, a foul odour suggesting tom cats and this is most marked at night. *O. morio*, the Green-winged Orchid, is rather similar, but is a shorter plant without the leaf spots of *O. mascula*, and with green-veined hoods to its flowers that are typically of a glorious mulberry colour, though no species varies so much in tint, all shades to pure white being frequent. The species is locally common in basic pastures, but is as irregular in appearance as *O. mascula* is regular. It seems to be getting scarce in S.E. England, probably through increased cultivation as it is still common in the west and midlands. The marsh orchids form a perplexing group to the novice, but are now fairly well sorted out into about 5 species and numerous striking hybrids. The two commonest forms are *O. praetermissa*, a purple-flowered plant also common in the Low Countries and France north of Paris, and *O. latifolia*. This latter has been shown recently by Pugsley, in a masterly piece of research, to be the original *O. latifolia* of Linnaeus (though for a century called *O. incarnata* by British botanists). It has flesh-coloured, lined flowers with recurved lips. The dwarf *O. purpurella* occurs in the north, and *O. majalis*, a mid-European species, has an atlantic sub-species, *occidentalis*, which Hall has shown to be plentiful and widespread in Ireland in several forms. *O. majalis* and its forms can be distinguished by its long strap-like mid lobe to the wide lip. The marsh orchids are stout plants with hollow stems and tubers lobed like a hand (palmate). The two southern species have unspotted leaves. The nearly related spotted orchids differ in their taller, slendered forms, their solid stems, and the paler, more delicate flowers. Here are two species ecologically well marked: *O. elodes*, with a broad lip with a tiny mid lobe, being a plant of acid heaths and bogs, while *O. maculata* (often called *O. fuchsii*) has a strongly three-lobed lip, and inhabits woods and pastures on basic soils.

The "militaris" group of species next concerns us. We have mentioned already those rare and lovely plants, *Orchis Simia* (the Monkey Orchid), and *O. militaris* (the Soldier Orchid). These both have the hood well formed, as in *O. morio*, and lack the spreading floral leaves of the palmate marsh and spotted orchids, but possess a lip which

is five-lobed. This resembles in a fantastic way a human body in *militaris*, and that of a red monkey (in white combinations!) in *Simia*; but the plate of *Simia* can convey only a partial idea of the wonderful delicacy and beauty of the flowers of this species. *O. purpurea*, the Lady orchid, or "Maid of Kent," is in the opinion of many, including the writer, our loveliest orchid, if not our loveliest British wild flower. To those who have seen her, standing up stately and erect from her large shining deep green leaves, with her pale flowers and their deep purple hoods gleaming in the gloom of the beech wood or chalky thicket, she will always leave an impression of regal dignity, as befits such a queen of the Kentish woods. The flowers are variable in colour and shape, but have the general form of a Victorian lady in a pink spotted crinoline with a green and purple mottled bonnet. This tall species is thought to be nearly extinct by many, even among botanists, outside the county where it grows, but it still occurs from one end of Kent to the other, and probably inhabits still at least a hundred stations. The writer knows (but will not reveal!) several chalk scrub areas where in good years the species can still be seen in hundreds—a sight to be remembered. The labellum bears peculiar projecting groups of red papillose cells, which occur to a less extent in the near relatives *Simia* and *militaris*. At present it does not appear to occur elsewhere in Britain, though it is common on the Continent. In Kent, however, there are two geographical races, a shorter Western dense-flowered form with wider flowers, and a taller Eastern lax-flowered form with narrow flowers. Darwin thought the species to be dying out from insufficient pollination, but the writer has found it to bear seed in good quantity, though insect visitors are rarely seen.

Orchis ustulata, the Dwarf or Burnt Orchid, is a very charming species, like a miniature *O. purpurea*, with a very dark hood, and a comical lip looking like a white clown's suit with a few big pink spots. It is both very local and irregular in appearance, and appears to be decreasing fast in most of England, though it holds its own well on chalk downs near the sea in Kent, E. Sussex and Dorset; in its liking for sea cliffs it resembles *Ophrys aranifera* which has a similar distribution. *Aceras anthropophora*, the Man Orchid, is rather like a yellow and green Monkey Orchid, to which species it is closely related, but lacks a spur. It is extremely plentiful on the Kent chalk, common in mid-Surrey, but rare elsewhere, though it still occurs in about a dozen counties in odd spots, and may be increasing again. The pink dome-spiked, foxy-scented Pyramidal Orchis, *Anacamptis pyramidalis*, differs from *Orchis* in having both pollinia attached to a common "saddle." Darwin thought this almost the most wonderful of our orchids in its pollination mechanism. It is interesting in that it is almost the only downland orchid which will rapidly colonise neglected arable land. It appears in a few years while most other species seem to need practically aboriginal turf for their home. Bee Orchis follows it next. The Fragrant Orchid (*Gymnadenia conopsea*) is one of our commonest species, having two forms whose status is uncertain; the smaller grows on downs, the greater form in fens. The two Butterfly Orchids (*Platanthera*) have white flowers more like moths than butterflies and have long spurs which are visited by long-tongued moths at night, when the flowers are deliciously fragrant. *Herminium*, the tiny and local musk orchid has also a strong scent, honey-like in type; this is a deception, the flowers having neither spur nor honey.

The most quaint and interesting species, however, are those of the genus *Ophrys*, which imitate insects. The labellum of the Early Spider Orchid, *Ophrys aranifera*, is a wonderful replica of a garden spider, especially when rather faded; it has a furry, heart-shaped body, with a bluish metallic patch like the Greek letter π, and even two eyes! *O. muscifera*, the Fly Orchid, is an even better replica. *O. apifera*, the Bee Orchid, is a less convincing imitation, as also is the even more elaborate lip of *O. arachnites*, the rare Late Spider Orchid, now confined to some eight spots in Eastern Kent. *O. apifera* has long-stalked pollinia which, if not removed by bees, fall forward and effect self-pollination; this may be one reason why the Bee Orchid is commoner than its insect-dependent allies. A suggested reason for the mimicry of these species is that they come from the North coast of the Mediterranean, from dry heavily grazed hill pasture, where their flowers, suggesting stinging insects, ward off cattle and sheep; the problem, however, can never be certainly solved.

Space forbids the mention of many more species. We must, however, allude to the celebrated Lizard Orchid, considered by the popular Press as our "rarest British plant." Actually this species has occurred on nearly a hundred occasions in Southern England, and might become common if allowed to seed and not always dug up when found. Our second commonest species, the Twayblade, is not showy, but has a remarkable pollen mechanism by which the pollinia are shot out complete with a drop of adhesive gum, on to the head of insects touching the labellum. We have, too, the Helleborines (*Epipactis* and *Cephalanthera*), a complex woodland series, fertilised mostly by bees or wasps, though some are self-fertile. Lastly we will mention the showy and rare Ladies' Slipper (*Cypripedium*) which, unlike all our other species, has two fertile anthers over its huge pouched lip.

May I end with an appeal to flower lovers, and botanists also, to be sparing in cutting the flowers of our wild orchids, and not to dig them up at all if in the least uncommon? The cultivation of most of our orchids is, as the writer knows well, a well nigh impossible task at present, and will be until we better understand the biology of this enthralling family.

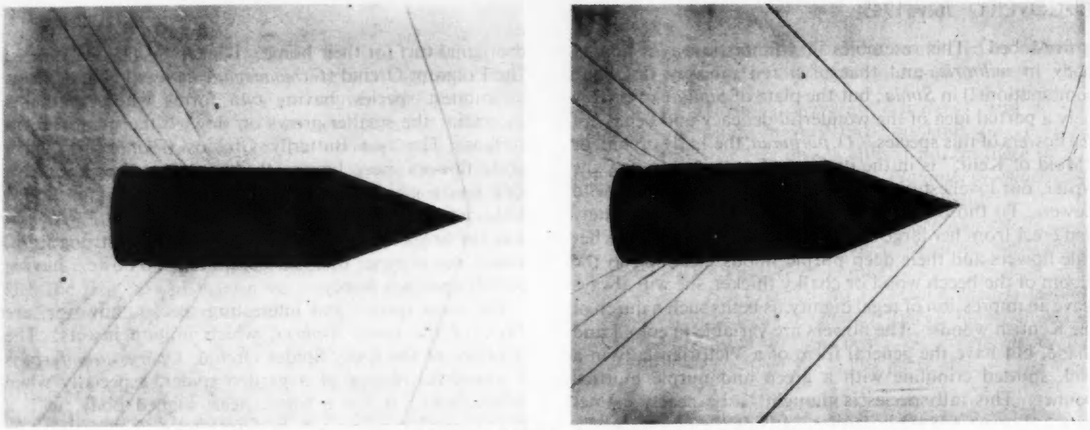


Fig. 1.—Photographs of a conical-nosed shell in flight at supersonic speeds. The heavy black line emanating from the nose is the Shock Wave. Speeds of flight are (*left*) 1·16 times that of sound, i.e. $M = 1·16$, and (*right*) $M = 1·576$. (These photographs were obtained by Maccoll at Woolwich and were originally published in the Proceedings of The Royal Society (A, **159**, 1937)).

Problems of High-Speed Flight

J. BLACK, M.Sc.

In peace-time, the gradual raising of the world air speed record up to what, at that time, seemed the fantastic speed of over 400 m.p.h. caused much excitement and comment. With the development during the War, however, of rocket-propelled projectiles and jet-propelled aircraft, the attainment of the speed of sound—762 m.p.h., at sea-level—is spoken of as though it were a normal continuation of the increasing efficiency of design, instead of being recognised as the solution of entirely new and extremely complex problems. The purpose of this article is to discuss briefly the phenomena which occur when the speed of sound is being approached and exceeded, in order that the difficulties to be overcome before flight at these speeds is possible may be appreciated more generally.

Compressibility

As with so many other branches of technical advance, the study of these new problems has brought into being what might be termed a new scientific subject, that of Gas Dynamics. Strictly speaking, this could be considered as a specialised part of the general subject of aerodynamics, but the need for differentiation is clear if the historical development of the subject is considered. The analysis of the motion of a fluid gave rise to the classical subject of Hydro-dynamics, which was so extensively developed in the last century. The fluid considered in all this work was regarded as incompressible, i.e. its density remained unchanged throughout, in spite of changing pressure, meaning that the results obtained could be applied to the flow of a fluid such as water.

When the aeroplane became a practical possibility, the knowledge obtained from Hydro-dynamics had to be applied to the analysis of the motion of a body through a fluid different from water, namely air, and this new application was called Aero-dynamics. The new subject, however, retained one very important postulate in common with hydrodynamics, which justified the adoption of many of the known results. The air was considered to be an incompressible fluid, analogous to water. In view of the common use to-day of compressed air as a means of transmitting force, showing that air is, in fact, quite easily compressed (that is, a change of pressure is accompanied by a change of density), this postulate of "incompressible air" may seem somewhat sweeping, but in actual fact, until quite recently, it was a justifiable one.

The reason for the justification is that when air, or, in general, any gas, is flowing past fixed boundaries at a speed less than half that of sound (for air at sea-level, 381 m.p.h.) the density changes consequent upon the pressure changes are so slight that they may safely be ignored. This applies equally well if it is the air which is at rest, and a body such as an aircraft or a projectile which is in motion at this speed, since it is purely a question of relative motion between the air and the boundaries.

The break-down of the postulate was indicated from three separate sources. The investigation of the flight of shells and bullets towards the end of the nineteenth century, the study known as External Ballistics, showed that as the speeds of flight of the projectiles rose up to that of sound peculiar changes took place, which could be ascribed to the density changes occurring round the body. These will be discussed in some detail later.

Then came the steam turbine, in which the steam flows at high speed through the nozzles and blading. Here, too, it was noted that the density changes due to the high speed were causing peculiarities of flow.

With aircraft, the postulate was justified up to the time of the advent of airscrews rotating at high speed. Due to the high rotational speeds the tips of the airscrew blades were moving at speeds in the neighbourhood of that of sound, and the behaviour of the tip sections was found to be different from that of sections nearer the hub, which were moving at much lower speeds.

The feature common to these three apparently unconnected cases is, of course, that due to the high speed of flow the pressure changes are sufficient to cause a compression of the working fluid, the air in the case of the shell and airscrew, and the steam in the case of the turbine. This phenomenon, whereby compression in the fluid takes place, is referred to as *compressibility*.

We can now see wherein the difference between aerodynamics and gas-dynamics will lie. In the former, we treat the density of the fluid as a constant, but in the latter we must consider it as a function of position and time, along with the other variables of flow. Naturally enough, this extra variable makes the subject of gas-dynamics more complex, and as yet it is not nearly so highly developed as hydro-dynamics. With the increasing need for knowledge of the subject, a great deal of attention, both experimental and theoretical, is being paid to it.

A New Conception of Speed

Before we proceed to examine the effects of compressibility, we must establish a new term for speed, and, in doing so, it will be made clear why the speed of sound is always used as our reference point. While we regard air as an incompressible fluid, the density is a constant, and we can use the speed of flow alone for a direct comparison. If, for example, we were investigating the increase in the bending moment at some point in the structure as the speed increased, we could say, "At 250 m.p.h. the bending moment is so much, and at 300 m.p.h. it has increased to so much." But if compression is taking place and the density is changing, 300 m.p.h. by itself means nothing unless we also know the density of the air at the same time. To have to give results in terms of speed and density would be extremely cumbersome, and in order to get a simple unit we introduce the speed of sound.

Our reasons for doing so can be seen at once when we remember that the speed of sound in a gas depends upon the pressure and density prevailing. If, then, we quote the speed of flow as a ratio to the speed of sound under the same conditions of pressure and density, the changing density is taken care of, as both speeds are dependent on it. This new unit of speed, which will just be a number with no units, is termed the *Mach Number*, after Ernst Mach, the Austrian physicist, who did much work on high speed phenomena. This unit is given the symbol M. The range covered by our new unit will be appreciated from the following example. We have already seen that the speed of sound in air at sea-level is 762 m.p.h., so a speed of 381 m.p.h. is equivalent to a Mach Number, $M=0{\cdot}5$. But the speed of sound in air at 25,000 feet has fallen to 694 m.p.h., due to the reduced pressure and density prevailing at that altitude, and consequently a speed of 347 m.p.h. at that height also has a Mach Number equal to 0·5.

We thus have two ranges of speed—*subsonic*, for which M is less than 1, and *supersonic*, for which M is greater than unity.

Shock Waves

In investigating compressibility we make use of a photographic means of rendering visible the regions of compression in the flow. Fortunately, this is quite simply done, as the refractive index of a gas depends upon its density; consequently, if a beam of light is directed across the paths of flow it gets refracted by any compressed portion of the gas, and this compressed portion thus shows upon the screen or plate as a region of darkness. This "direct-shadow" method can be made even more sensitive by the use of an optical system known as the "Schlieren" or striation method.

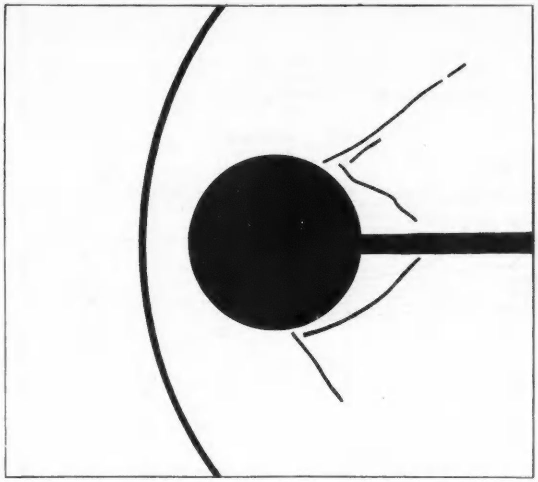


FIG. 2.—The Shock Wave set up when air flows at supersonic speed past a cylinder. Note that it is formed ahead of the body, unlike the wave from the projectile in FIG. 1. This is a sketch of the photograph obtained with the cylinder fixed in a high-speed wind tunnel. The lines emanating from the cylinder itself are subsidiary waves.

Fig. 1 shows photographs of a conical-nosed bullet travelling at supersonic speed taken at Woolwich by Maccoll. The heavy black line emanating from the nose indicates a region of compression which is confined to a very narrow sheet sloping downstream like the bow-wave from a ship. That is to say, the density change occurs in a very abrupt manner, and for this reason it is called a *shock wave* or *compression shock*.

A physical interpretation will be made easier if we think of a blunt-nosed body moving supersonically through the air, rather than of a pointed bullet. Some air in front of the blunt nose will not be able to flow away downstream past the nose, and will thus be pushed forward against the still air ahead. Where the two regions of air meet, the cushion of air moving forward supersonically, and the still air ahead, there will occur an abrupt compression, which is, in fact, the shock wave. Fig. 2 is a sketch made from a photograph of air flowing at supersonic speed past a cylinder fixed in a high-speed wind tunnel, and it will be seen that the shock wave in this case is of spherical form and is set up ahead of the body.

Anyone who has been in a blunt-nosed rowing-boat will have noticed that the bow-wave does not emanate from the bow, but is actually set up a short distance ahead of it, and from there it slopes downstream. This is exactly similar to the phenomenon occurring with air that I have described above, but in the case of water the region where the water being pushed forward by the bow of the boat

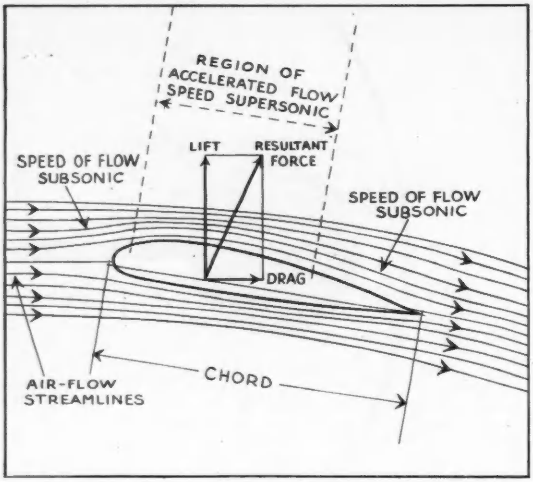


FIG. 3.—Diagram to illustrate the regions of flow around an Aerofoil Section. The resultant force on the aerofoil, due to the differing pressures on the upper and lower surfaces, is resolved as shown into two forces, the Lift and the Drag.

meets the still water ahead shows up as a "piling-up" or crest, since it is an incompressible fluid. With a gas the region of "piling-up" takes the form of a wave of increased density, due to the compression.

The shock wave should not be confused with a sound wave. In a sound wave there is no appreciable increase in the density of the gas, and the flow of the fluid through it is unaffected. It is only to be expected, however, that such an intense and abrupt change as that which occurs in a shock wave will have a considerable effect on the flow. The shock wave is distinguished, too, from the sound wave in that its speed of propagation is greater. This fact is the explanation of the interesting phenomenon whereby the explosion of a V.2 was heard before the sound of the projectile's passage through the air. The blast wave from the explosion may be considered as a shock wave, and consequently it travels faster than the sound waves which have been propagated before the explosion even takes place. The phenomenon may be briefly illustrated in the phrase used in army instructions—"the crack, then the thump". The crack is, of course, the reaction of the ear-drum to the impact of the shock wave from the projectile, and the following thump is the sound coming from the gun which originally fired it.

The effect of the shock wave on the flow is shown by the change in the *drag*, or resistance to motion, of a body as its speed through the air increases. It is found that the drag in the subsonic region is fairly constant, but as soon as the speed of sound is reached it increases abruptly up to ten times its original value. This sudden increase in drag is due to the formation of the shock wave, which only occurs at and above this speed.

It will be seen from the photographs (Fig. 1) that as the speed of flight increases from $M = 1{\cdot}16$ up to $M = 1{\cdot}576$ the shock wave slopes further back, making a more acute angle with the path of flight. The angle of the wave is, in fact, an indication of the speed of the projectile.

The formation of shock waves explains why projectiles which are to travel at speeds greater than that of sound do not have the conventional pear-drop streamline form. For example, a bomb which will always travel at a subsonic speed is streamlined, whereas a shell has a conical nose, in order that the shock waves formed at supersonic speeds should take as little effect as possible. The blunt rounded nose is the ideal shape for subsonic speeds, but is the worst possible one for supersonic ones.

The Aerofoil at High Speeds

The foregoing discussion on the formation of shock waves around projectiles is a necessary preamble to consideration of the behaviour of an aeroplane wing at high speeds, because the flow of air past the wing is similarly affected by the presence of shock waves.

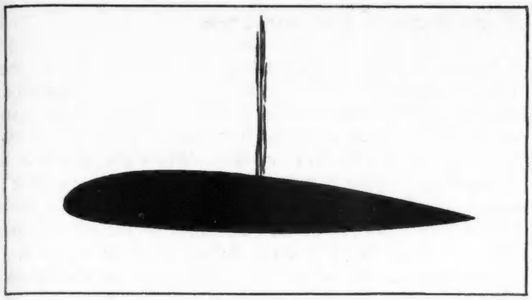
To understand why this is so, we need to know how it is that an aeroplane wing does enable us to fly in heavier-than-air machines. For this reason, we explain briefly the action of an aerofoil, which is the name given to the cross-section of an aeroplane wing.

An aerofoil section has the shape shown in Fig. 3, from which it will be seen that the upper surface is curved, the greatest curvature being towards the leading edge. When the air flows over this curved surface it has to accelerate, in order to join up again with that part of the air-stream which has passed along a comparatively straight path under the section. Due to this increased speed over the top surface, the pressure there becomes reduced, with the result that in actual fact an aeroplane is sucked up by the suction over the top surface of the wing, rather than lifted up by the pressure on the bottom surface. For convenience the total resultant force on the aerofoil is resolved into two forces; the *lift* force, acting at right angles to the air flow, and the *drag* force, or resistance to forward motion, acting along the air flow.

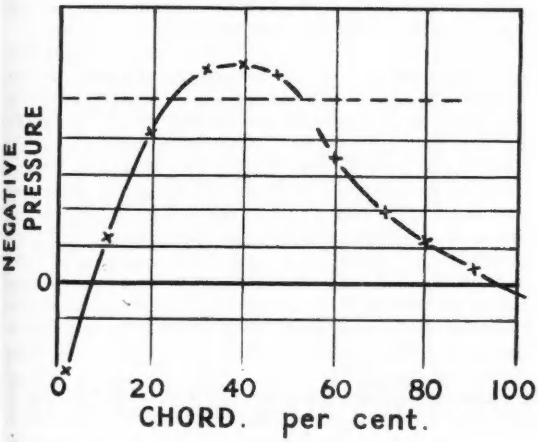
The acceleration of the air flow over the top surface is such that the maximum speed of flow there is approximately $1\frac{1}{2}$ times that of the aerofoil itself through the air; for instance, if the aerofoil were moving at 300 m.p.h. the relative speed between the top surface and the air-stream would be about 450 m.p.h.

Now suppose the aerofoil is moving forward with a speed, Mach No. $= 0{\cdot}75$ (i.e. at sea level $0{\cdot}75\ M = 0{\cdot}75 \times 760 = 570$ m.p.h.; or at an altitude of 25,000 feet $0{\cdot}75\ M = 0{\cdot}75 \times 694 = 520$ m.p.h.). In this case the relative speed of flow over the top surface will be accelerated up to a value of $0{\cdot}75 \times 1{\cdot}5 = 1{\cdot}125$, or, in other words, there is induced over the top surface a region of supersonic speed, even though the aerofoil itself is moving subsonically. That is to say, going from the leading edge to the trailing edge of the aerofoil, we have firstly a subsonic region, followed by a supersonic one, and finally a subsonic one again (Fig. 3).

From our discussion in the last section, we know that air flowing at supersonic speed—for example, the cushion of air ahead of the blunt-nosed body—cannot change smoothly into flow at subsonic speed; where the two regions meet a shock wave is formed. We would expect, therefore, that on the top surface of the aerofoil a shock wave would be formed at the boundary of the supersonic and subsonic region and, experimentally, we find this to be the case.



(*a*)—The Shock Wave formed at the boundary of the supersonic and subsonic regions on the upper surface. Sketch made from the original photograph obtained in a high-speed wind tunnel.



(*b*)—Pressure measurements made along the upper surface simultaneously with the taking of the photograph above. Note that the break in the curve occurs at the same distance back from the leading edge as does the shock wave.

FIG. 4.—RESULTS OBTAINED IN TESTS ON THE AEROFOIL SHOWN. THE AIR FLOW IS FROM LEFT TO RIGHT, WITH A SPEED, M = 0·6.

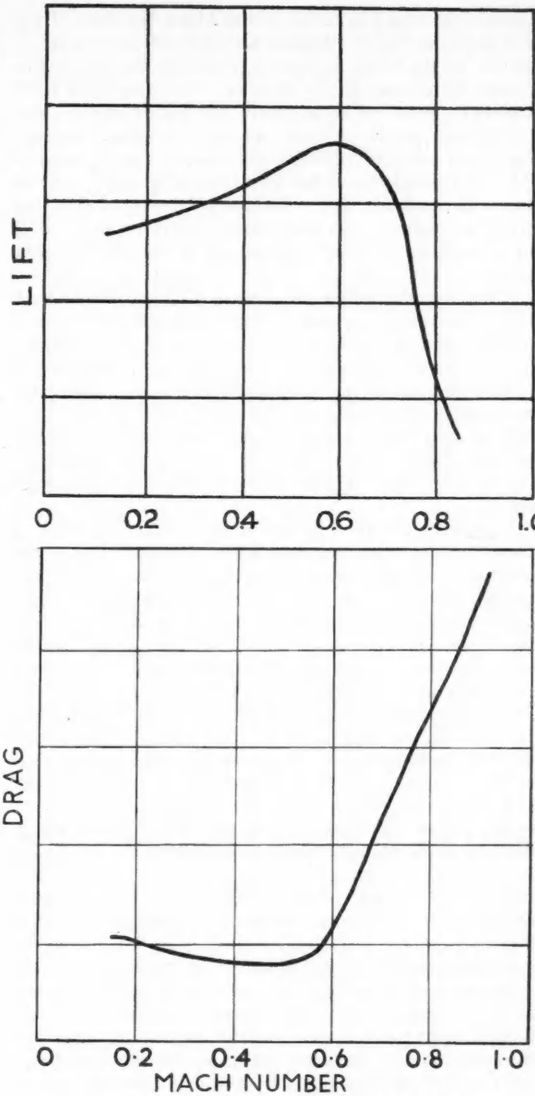


FIG. 5.—Influence of the Mach Number on the Lift and Drag of an aerofoil section.

The results obtained from tests on a conventional aerofoil section, made in a high-speed tunnel, are shown in Fig. 4. As already mentioned, it is the relative speed between the air and the body which matters; hence it comes to the same thing if we hold the aerofoil at rest, and direct a high speed stream of air past it: this is what is done in a wind tunnel experiment. Pressure measurements at a number of points along the upper surface were made, and simultaneously photographs of the type mentioned earlier were taken. A word of explanation for the method of representing the pressure measurements in Fig. 4b is needed. The distance of the pressure hole from the leading edge is plotted horizontally, in terms of percentages of the length of the chord, while the negative pressure at the pressure-hole is plotted vertically.

In Fig. 4a the shock wave formed shows up as a black line, perpendicular to the air stream, and its presence is confirmed by the break in the pressure curve (Fig. 4b). The horizontal dotted line drawn on the pressure figure marks the pressure which by calculation corresponds to the air stream flowing with the speed of sound. It will be noted that the break in the curve occurs at this pressure, thus confirming that the shock wave is formed at the boundary of the supersonic and subsonic region, where the speed is exactly that of sound.

Since the lifting power of an aerofoil is the basis of mechanical flight, what we are really concerned about is the manner in which its performance will be affected by the formation of the shock wave.

To investigate this we plot the curves for the lift and drag, obtained from balance measurements in the tunnel,

against the speed in terms of the Mach Number. These are shown in Fig. 5. We see that up to $M=0{\cdot}6$ the lifting power of the wing is slightly increased, but for higher speeds there is an abrupt decrease. The drag stays fairly constant up to the same speed, but for M greater than 0·6 it rises up to ten times its original value. For this particular aerofoil, photographs showed that a speed of $M=0{\cdot}6$ coincided with the formation of a shock wave on the upper surface. The behaviour of the aerofoil at this stage is referred to as the *compressibility* or *shock stall*, and the speed at which this occurs is the *shock stalling speed*.

Thus, the effect of the shock wave is very serious indeed. Once it forms, the conventional type of aerofoil is virtually useless, because it will no longer lift, and its resistance to motion would require an enormous thrust to overcome it.

Here then is the real problem of high speed flight. We have to develop new aerofoil sections which will not "shock stall" until a much higher speed than $M=0{\cdot}6$ is reached. Better still, of course, would be an aerofoil whose performance was little affected by the presence of the shock wave.

Very little can be said now about the development of these new sections, but two main differences from the older conventional ones can be given. The sections are much thinner; whereas the older ones had a maximum thickness of from 15 to 16 per cent of the chord, the new high speed ones do not exceed 12 per cent. Fig. 3 shows that the curvature of the conventional section was such that the point of maximum thickness was approximately 25 to 30 per cent of the chord back from the leading edge. In the new section, however, the point of maximum thickness moves back to somewhere around 40 per cent of the chord, as this is found to help delay the onset of the shock wave.

Limitation of the Airscrew

Shock stalling of the aerofoil sections is one of the reasons why a limitation to the usefulness of the airscrew as a means of propulsion has arisen. An airscrew consists of blades arranged around a hub, the cross-section of the blades being an aerofoil section. When the airscrew is rotated each blade acts like a wing, developing a "lift", which in this case does not act vertically, but as a horizontal thrust pulling the aircraft through the air. As the speeds of the blades through the air rises the position is eventually reached when the tip sections of the blades "shock stall," and so cease to develop any thrust.

The new aerofoil sections are not a great help, either, because they are much thinner and it is difficult to make the thinner blade withstand the great stresses which arise at such high rotational speeds. While the airscrew has still some way to go before being superseded, it is clear that a new method of propulsion was called for at high speed, and this need has given rise to jet propulsion.

Many more difficulties arise at high speed, but summing up we can see that there is one outstanding phenomenon. When a gas is flowing at supersonic speed it cannot be slowed down to a subsonic one without the formation of a narrow region of compression, called a shock wave. The presence of a shock wave considerably affects the flow of the gas, and results in a great increase in the resistance to motion of a body placed in the stream. In the case of an aerofoil it causes a loss of the lifting power.

We are at one of the most interesting stages of aeronautical development, because the solution of the problems set up by the shock wave and allied phenomena calls for work involving many branches of science, and the goal to be achieved is that most romantic sounding one—flight faster than sound.

FAUNA OF BURMA (*Continued from page* 220)

Some mammals have great curved claws for hooking over branches; the sloths of South America provide the best example of this adaptation, but the pangolin found in Burma uses the clumsy looking claws of its fore-feet in the same way. Some climbing animals use their fingers merely as hooks, but many of them are able to grasp branches and twigs between the four fingers and an opposable thumb; often there is an opposable big toe as well. One Burmese animal, the slow lemur, is thus able to climb down a tree head first, gripping with its feet behind; it generally feeds upside down, holding its food in its hands and hanging on with its feet. Many geckos have their toes expanded into suction discs which enable them to climb on smooth surfaces, up the walls of houses and across ceilings, or along the lower sides of branches.

The fauna of the Oriental Region seems rather to specialise in flying and attempts at flying; in addition to the many species of birds, bats and insects that have mastered the art and have representatives all over the world, there are here mammals, reptiles and amphibia that have developed, quite independently and in different ways, membranes which can be spread out in a horizontal plane, and enable their owners to glide through the air from branch to branch and from tree to tree. In the flying squirrels and the flying "lemur" the membrane is stretched along the flanks between the fore and hind limbs; in the flying dragons it is stretched over some of the hinder ribs which are very much lengthened for the purpose, and in the flying frogs it is the toes that are much elongated, and the membrane is stretched between them.

One of the advantages of arboreal life lies in the relative abundance of places for concealment during the sleeping hours whether these are at night or during the day time. Most terrestrial animals, other than the ungulates (hoofed mammals like deer, sheep and horses) which rely on alertness and fleetness of foot to escape from their enemies, hide during the day in burrows which are laborious to construct or in caves which are difficult to find. Such animals, once they have made or found a home, tend to stick to it. On the other hand arboreal animals have no difficulty in finding temporary shelters and hiding-places, and do not usually have permanent homes, except, perhaps, for short periods in order to bring up a family. (One consequence of this is that few arboreal animals, and practically no ungulates, can be house-trained. There is no natural instinct for cleanliness and without this instinct as a basis training is impossible. It is not a matter of intelligence, for rabbits and hedgehogs are not difficult to house-train; but horses and monkeys cannot be made to understand. This is one of the main objections to the latter as pets.)

(*To be concluded.*)

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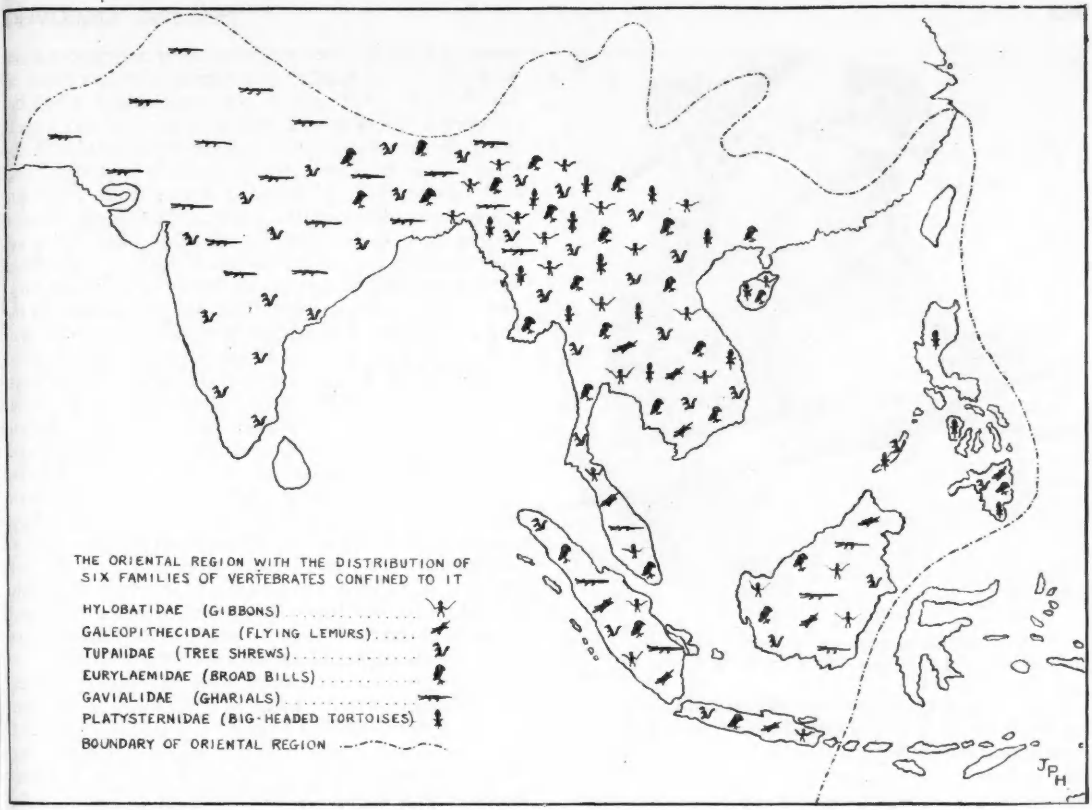


FIG. 1.

The Fauna of Burma and Adjacent Lands

J. P. HARDING, Ph.D., F.Z.S.

IN discussing the fauna of a country such as Burma it is unnatural to be limited by political frontiers which are so notoriously arbitrary and which rarely coincide with natural boundaries separating one type of fauna from another. The fauna of Burma is typical of that part of the world known to zoologists as the Oriental Region. This is one of the six regions into which the world is divided on the basis of the geographical distribution of animals. Each region possesses a characteristic fauna which differs from that of a neighbouring region in the presence of some groups of animals and the absence of others, or by the predominance of this or that type. The Oriental Region comprises India and Ceylon, Burma, Siam, South China and Formosa, the Malay Peninsula, the western East Indies—Sumatra, Java, Bali, Borneo, and the Philippines. The other five regions are (1) the Palaearctic Region extending over the whole of Europe and Asia north of the latitude of the Himalayas and also including North Africa. (The fauna of North Africa is much more like that of Southern Europe and Persia than it is like that of the rest of Africa.) (2) The Ethiopian Region including all Africa south of the Sahara, part of Arabia and Madagascar. (3) The Nearctic Region: most of North America. (4) The Neotropical Region: South America, Central America and the West Indies. (5) The Australian Region covering Australia, New Zealand, New Guinea, the East Indies east of Bali, and the Polynesian Islands.

The fauna of a country is determined partly by its climate and vegetation, partly by its relationships with other countries, i.e. its accessibility to the immigration and exchange of species, and largely by the way these relationships have changed in the past. During the period of the evolution of the modern groups of animals climates have changed and barriers to migration in the form of mountains, deserts or seas have arisen here and disappeared there. The fossil record indicates that the higher groups of animals evolved in the great land masses of the Northern Hemisphere which are known to be of great antiquity. The climate here was evidently much warmer once as there are fossils of rhinoceroses, hippopotami, elephants and crocodiles in Europe where they were once quite as abundant as they now are in the tropics. At an earlier age than this there were even marsupials in Europe. In the Southern hemisphere three ancient land masses

FIG. 2.—The flying "lemur", *Galeopithecus volans*. (*From "The Cambridge Natural History", Volume X*).

corresponding to the Australian, Ethiopian and Neotropical regions, while remaining always distinct from one another, each in turn became temporarily united with some part of the northern land. Whether this was brought about by continental drift or otherwise need not be discussed here.

While each union lasted the animals present at that particular time in the north migrated into the southern lands, and after the union was broken they continued to evolve along independent lines. Australia can only have been united at a very early age, when the mammals had not evolved beyond the pouched marsupial stage. Since this time the marsupials here have evolved in many directions to give the present Australian fauna; but in other lands, except for the opossums of America, the marsupials have succumbed in competition with the higher mammals as these arose. The South American and Southern African lands seem to have united and separated again several times with the north, each time receiving an influx of, first the lower, and then the higher forms of mammals, birds and reptiles. During much of this time the climate of Europe and south-eastern Asia was mainly sub-tropical and the present Oriental region would have formed part of the great Palaearctic land. With the rise of the Himalayan mountains and the Tibetan plateaux and the deterioration of the European climate, the Oriental region became separated off, retaining many of the warmth-loving animals which formerly roamed over the whole area, but in the north were now killed off by the cold. The whole of the Oriental region was continuous until at least late Pliocene times, after which time the Philippines and the other islands belonging to it separated off. This is the explanation for the great similarity between the fauna of Java and Bali to that of India. The fauna of Bali is in fact more like that of India, allowances being made for the great difference in size, than it is like the fauna of Lombok, the next little island only fifteen miles from Bali; for instance, such typically Indian birds as barbets, weaver birds and trogons are plentiful in Bali but completely absent from Lombok. There are also a great many forms common to both the Palaearctic and the Oriental regions, such as the hedgehog, weasel, bear, dog, rabbit, wren, finch, hoopoe and viper families which are represented in Java and Bali, but are to be sought for in vain further east. In Lombok, on the other hand, there are the screaming cockatoos and friar birds and the strange mound-building megapodes, all allied to Australian birds and entirely wanting in Bali, Java or anywhere else in the Oriental region. This abrupt demarcation between Bali and Lombok is a measure of the extreme isolation of the Australian region we have already described, and is known as Wallace's Line. Although the climates and the terrestrial environments of the two islands are almost identical there are greater differences between the faunas of Bali and Lombok than there are between the islands of Great Britain and those of Japan. Just as the British Isles have only comparatively recently been separated from Europe, so were the islands of the Malay Archipelago as far as Bali formerly part of the same land mass as India and Burma. On the other hand the rest of the chain of islands, from Lombok to Timor, have been separate from any large land mass for at least the whole of the period during which modern types of animal have been evolving.

The division of the world into six zoogeographical regions should only be taken as a summary of the geographical distribution of animals as found to-day. Each species of animal has its own distribution which does not necessarily conform to this division and which can only be interpreted in terms of the historical evolution of the animal and its environment taken as a whole. Tapirs, for example, are found to-day in Tenasserim and Malaya in the Oriental region and also in South and Central America in the Neotropical region. Fossil tapirs are, however, known from Europe, China and North America in the middle and late tertiary deposits, and it is clear that they once inhabited the whole extent of the luxuriant hot, damp forests which then extended over the whole of the Northern Hemisphere almost to the Arctic Circle.

We have seen how the Oriental and Palaearctic regions have been derived from the largest and most stable of the ancient land masses, and how this has been the source from which all other regions have been supplied with successively higher forms of life. From the climatic and zoological aspect it is the Oriental region which to-day most closely resembles the great northern continent of Miocene times. The ancient unchanging character of the jungle-clad hills of Burma and neighbouring lands has not, however, led to an ancient unspecialised fauna. On the contrary, the very stability of the environment has allowed natural selection to play its full part in the competition and struggle for existence without interference from sudden changes in climate. Evolution has proceeded through the ages without interruption, until to-day the animals are extremely well fitted, each to its own niche, in the environment. This is particularly well shown in the extraordinarily detailed way in which so many of the insects and reptiles are camouflaged; their colours and patterns and even shapes are specially adapted to resemble some constantly occurring feature of their surroundings.

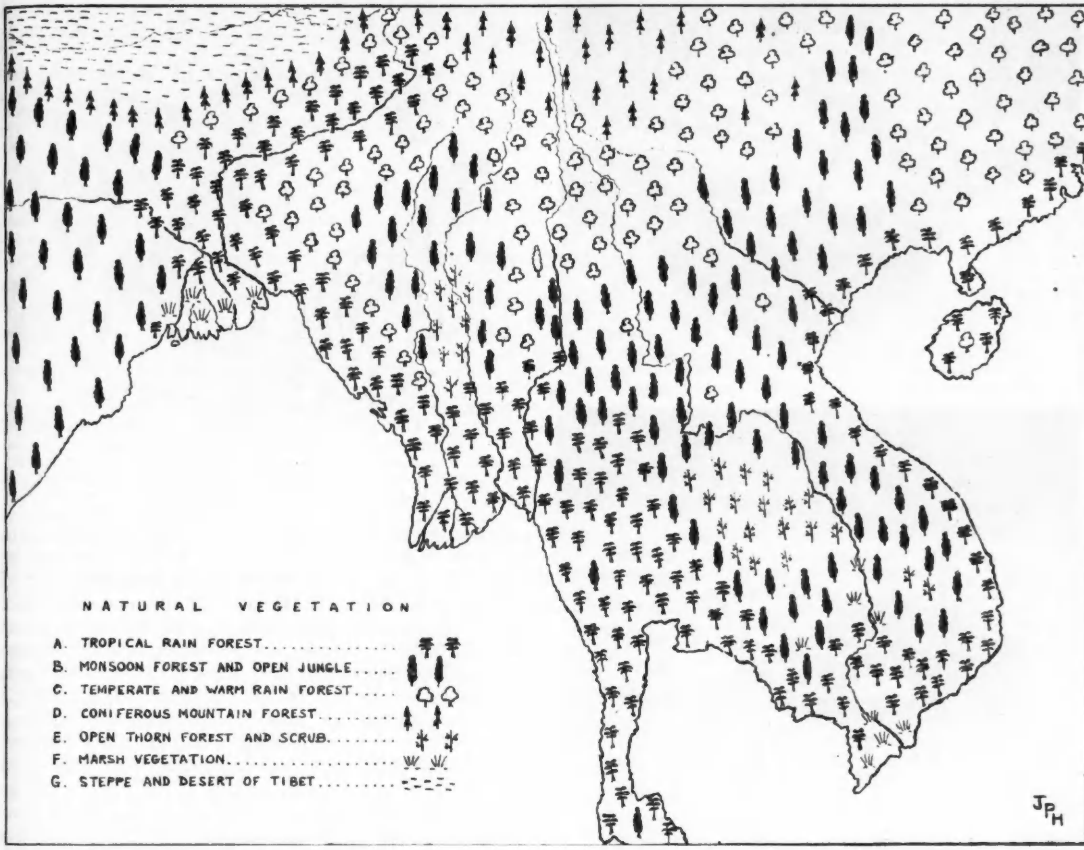
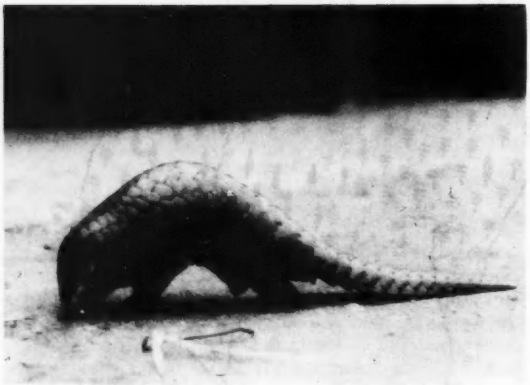


FIG. 3.—The natural vegetation of Burma. *A*: Tropical rain forest, hot and wet at all seasons, with luxuriant growth of evergreen trees, climbers, tree ferns, woody epiphytes, orchids, lianas and bamboos. *B*: Monsoon forest and open jungle, hot at all seasons, wet or very wet in summer, dry in winter. A patchwork of teak and many other types of deciduous forest bare of leaves in the dry season, with lianas, herbaceous epiphytes in the tree tops; thickets of bamboo on poorer soil. *C*: Sub-tropical and temperate rain forest. Warm, with heavy rains in summer and heavy dews in the forests in winter. Very varied, mostly evergreen vegetation, evergreen oaks, laurels, rhododendrons, tea, wistaria, lianas, epiphytes, and bamboo. *D*: Coniferous mountain forest. Cool. *E*: Open thorn forest and scrub. Hot and at times too dry to support a vegetation richer than scattered shrubs of acacia, tamarisk and euphorbia with thorn thickets, and teak in less arid places merging into *B*. *F*: Marsh vegetation dominant in deltas. *G*: High steppe and desert in altitudes above the tree line, with ice desert on the mountains.

Here also methods of flight or near flight have been evolved in squirrels, lizards and frogs, as well as the flying "lemur", *Galeopithecus*. Man has taken war to the jungle and flight plays a big part in his campaigning.

Emphasis has so far been placed on the ancient, unchanging nature of the climate and vegetation of Burma taken as a whole; lest this gives a false impression of monotony it must be explained that at the same time Burma has, and probably always has had, a wide range of environments. The land is hilly or mountainous, with the ranges running mainly in a north to south direction, that is more or less at right angles to the direction of the moisture-laden winds. Here we can only describe the different types of vegetation in very general terms. The climate of, Burma, and of India, is less monotonous than that of most tropical regions (which are hot and wet at all times of the year), for a climate dominated by monsoons has dry winters and very wet summers. There is, however, a belt of tropical rain forest all round the coast from the Bay of Bengal right round to South China. This rain forest resembles that of other tropical regions which are wet at all seasons, and is 100-feet or more high with evergreen, moisture-loving trees, palms, tree ferns, thick-stemmed lianas, and woody as well as herbaceous epiphytes and orchids. In the centre of the lower elevations to the south, where there are tropical temperatures with comparatively little rain, there is a xerophilous scrub of acacia, tamarisk and euphorbia. From here to the rain forest on the coast there is every gradation from thorn forest through open jungle to tropical monsoon forest.

The trees of the monsoon forests clothing so much of Burma, are less tall than those of the tropical rain forests, and are deciduous, losing their leaves in the dry season and growing them again with the arrival of the monsoon or a little earlier. Woody lianas and herbaceous epiphytes are plentiful, but there are few woody epiphytes. In



FIGS. 4 and 5.—The Pangolin, *Manis pentadactyla*. The powerful claws that are used for digging open ants' nests also enable the animal to climb. (*Copyright, Zoological Society of London*).

tropical rain forest there is an extraordinary variety of trees and no species dominates over the others; even the commonest species are difficult to find as there are only a few individuals in a given area, mixed with individuals of a great number of other species. In a monsoon forest the species are also mixed but not so strikingly and, in places, as in the teak forests which are of such great economic importance to Burma, one species may predominate In a teak forest the trees grow straight up to a height of 70–80 feet or more, and are accompanied by lianas; their epiphytes are mostly confined to the tops of the trees. Gaps in the forest are often filled with tall bamboo thickets; but grass is very scanty.

As one travels northwards in Burma the country becomes more and more mountainous. First come the foothills covered with open jungle containing ironwood, teak and banyan trees. This type of forest extends to elevations of 5,000 feet and more, and gradually merges into a denser sub-tropical and temperate rain forest with evergreen oaks, rhododendrons, tree ferns, wistaria, and with orchids, epiphytes and bamboos. Although the rainfall is confined to the summer months more rain falls here in this season than falls during the whole year over

FIG. 6.—A Flying Dragon, *Draco volans*. (*From "The Cambridge Natural History", Volume VIII*).

a comparable area anywhere else in the world, and even in winter when there is no rain the leaves of the trees are wet with dew. Further north the general elevation of the country reaches 10,000 feet, and although the latitude is still sub-tropical the climate is cool and the mountain forest mainly coniferous until it merges into the high steppes and deserts of the plateau of Tibet, where even the valleys are from 12,000 to 15,000 feet above sea level.

Such is the general picture of the vegetation of Burma. Grassland is practically absent, and nowhere are there vast monotonous tracts of vegetation. Not only is the climate and vegetation in a valley different from that on the top of a hill, and the conditions on one side of a hill different from those on the other; but there are also differences which reflect the very varied nature of the geological substratum, the vegetation on a poor soil being more xerophytic in type than that on a good soil. Patches of scrub, of bamboo, or of marsh are mixed in with areas of one type of forest here and another there.

Arboreal Types

As so much of Burma is forested a high proportion of the animals are arboreal. Arboreal mammals retain a number of primitive features which are lost by those specialised for other habitats. Greater freedom of movement of the limbs is required for climbing, and the elbow and knee are free and not tied down to the body as they are in deer, horses and other running animals. The shoulder joint is flexible and not restricted to movement in one plane, and the chest is broad, the collar-bone being retained. Both bones of the forearm, the radius and the ulna, are well formed so that the forearm can be rotated; and the wrist is supple with the full complement of bones. All five fingers inherited from the "pentadactyl limb" of the first land vertebrates, the early amphibia, are generally present. In squirrels and cats which have arisen from terrestrial ancestors, the nails are sharp and used for clambering up the trunks of trees, though in the latter their primary purpose is for the apprehension of prey.

[*Continued on page* 216

The Bookshelf

This Chemical Age. By William Haynes. (Secker and Warburg; pp. 288, 12*s.* 6*d.*).
Materials of To-morrow. By Paul I. Smith. (Hutchinson; pp. 140, 12*s.* 6*d.*).

CHEMICAL PRODUCTS, like power, are needed by all modern industry. This universality of demand indicates that the activity of the chemical industry is a measure of the activity of the industry of the nation as a whole. Moreover, if some sectors of chemical industry are weak, there is good reason to believe that this weakness will be carried through to the whole of industry. Haynes, a well-known American writer on chemical subjects, frequently throws light on facets of the British, German, and American industries. For example, he shows that the development of the sulphuric acid industry in Britain was necessary for the great expansion of the textile industry, otherwise Arkwright's spinning machine would have flooded the land with "grey goods". Later Perkin had to prepare pure benzene in order to be able to manufacture his mauve. The shortage of toluene held up the commercial synthesis of indigo until an alternative starting material was discovered.

To-day, in Britain, we face a great weakness through the lack of any considerable home petroleum-refining facilities. This is due to various causes such as Imperial strategy and agreements by the oil companies to refine in the countries where oil-raising rights are granted. Nevertheless in several points this country holds advantages over the U.S.A., as in the case of coal-distillation products, where we have more available per head of the population by reason of our large coal gas industry. But in the same way as the German dye industry grew up by the use of British coal tar crudes, we may observe that exports of crudes are now made from this country to the U.S.A. It would be much better for our national economy, and quite defensible on grounds of international division of labour, if we were to export the worked-up intermediates and not the crudes.

Britain's materials of to-morrow thus depend on chemical products, chemical processes, and chemical engineering. Paul I. Smith does not consider adequately the *ifs* and *buts*. Neither has he the well-rounded approach of the American author. Moreover he has a facility for failing to notice exciting industrial events which have occurred in this country, such as the development of magnesium extraction from sea-water. But this is bound up with the large degree of monopoly existing in Britain and the secrecy surrounding much of our chemical industry. One obvious result of this is that one-sided trade publicity material when transcribed into books gives a false impression of British industrial capacity.

The British genius for individual acts of discovery and invention is well brought out in the American book. So too is the American and German ability to organise collective scientific and engineering effort. The problem that now faces us, in the chemical field, as elsewhere, is the organisation of co-operative work to take the greatest advantage of and to enhance our powers of individual achievement.

SYDNEY GREGORY.

Experimental Electronics. By R. H. MULLER, R. L. GARMAN and M. E. DROZ. (New York, 1943, Prentice-Hall; pp. xv+330; 21*s.*)

THE techniques developed first for electrical communications (particularly amplification by thermionic valves and examination of variable phenomena with the cathode ray tube) have unlimited application in other fields of experimental science, and it is a very commendable aim to provide a book to initiate science students in general into the technique of using electronic tools. But since this book already has three joint authors, all chemists, would it not have been reasonable to add as fourth partner either an electrical engineer or an electron-physicist? One does not ask for undue mathematical rigour in such a book, but an engineer or physicist would avoid transgressions against mathematical decency such as occur in this volume.

The sections in the first chapter on calculation of circuit impedance could with advantage have been replaced by a simple table of formulae: the descriptive sections on radio parts could then have been correspondingly expanded to include, for example, mention of the importance of power factor in relation to the type of dielectric in fixed condensers, and accounts of ceramic condensers and of the colour code by which practically all radio resistances are now marked with their value. To the communications engineer, at any rate, the chapter on triodes seems unduly complicated by the omission of the normal equivalent circuit for the (hypothetical) linear triode, but on the other hand familiarity with the graphical characteristics is very valuable and applicable to the very real non-linear cases.

The authors are more at home when describing particular pieces of apparatus, such as photocells, voltage-regulated power supplies, valve voltmeters, amplifiers, oscillators and, in a final 30 pages, the characteristics of cathode-ray tubes and their associated time-bases and amplifiers.

The scope of this book fills a very real need, but in detail it is in many places open to criticism by anyone who is already familiar with the field of electronics; the present issue is stated to be the third printing, but one hopes there will shortly be a revised edition instead of a further re-printing.

D. A. BELL.

Oceanography for Meteorologists. By H. U. SVERDRUP. (Allen & Unwin, London, 1945; pp. 246; 12*s.* 6*d.*)

UNTIL the publication in 1942 of *The Oceans* by Sverdrup, Johnson and Fleming there was no comprehensive treatise on physical oceanography in the English language; this book by the first author extends the discussion of the many facets of the subject which have a bearing, both direct and indirect, upon meteorology. In the two books Professor Sverdrup deals with a fascinating subject, which has made much headway during the past twenty years, in a masterly manner. It is illustrated with excellent folding charts showing the currents of the upper layers, the surface temperature and salinity of the oceans. These are of direct interest to meteorologists. Their study requires that the factors controlling them be considered. The deep water currents of the oceans are in consequence included, with discussion of the factors which give rise to the currents, also the distribution of density, or pressure fields, in the oceans which the currents themselves cause, and from which the currents may be computed. These studies are germane to meteorology since the currents transport heat from one part of the globe to another. Moreover, compared with the land, heat penetrates deep into the sea owing to vertical mixing caused by eddy motion, which distributes the heat gained in summer over a relatively thick layer. Thus the sea stores, and transports in its currents, large quantities of heat. In winter the loss of heat takes place from a considerable layer of water and in consequence the difference in temperature at the surface between summer and winter is much less than at the surface of land. Circulation of heat in the sea, exchange between sea and atmosphere, gain and loss by radiation and evaporation, the effect of wind and waves, are discussed, together with the methods used in oceanography and the physical properties of sea water.

H. W. HARVEY.

Men of Science in America. By Bernard Jaffe (New York, Simon & Schuster, 1944; pp. 600; $3.75).

THIS book is rare good value even at the British price (22*s.* 6*d.*). It contains 19 biographies, the value of which is enhanced by the fact that the backgrounds are finely done. Both from the point of view of social history and scientific history, the individual subjects are described in such a way that they come to symbolise a phase in the development of American civilisation and a stage in scientific progress. The scientists whose lives are outlined here are Harriott, Franklin, Benjamin Thompson, Thomas Cooper, Rafinesque, Say, Morton, Henry, Maury, Agassiz, Dana, Marsh, Willard Gibbs, Langley, Michelson, Morgan, H. M. Evans, Hubble and E. O. Lawrence.

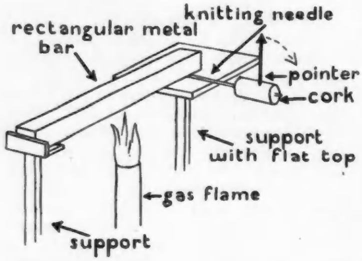
Though each biography forms a separate chapter, one gets the impression that the whole volume is considerably greater than the sum of its parts; one senses that the author's unity of plan is responsible for creating this effect. His approach can be summed up in the words "Science is an activity and not simply a body of facts. . . . A nations faces a problem which science attacks and solves"—a simple statement of the hypothesis that has of recent years transformed historical studies of scientific progress.

WILLIAM E. DICK.

Thermal Expansion

WHEN recently in these columns we talked about changing heat into work, we mentioned the most important devices by which this process is usually being carried out—the petrol motor and the steam engine. In both machines we make use of the fact that a gas when heated expands. In the petrol engine the gas which is heated is the air which is sucked into the cylinder before the explosion takes place, and in the steam engine we make use of the expansion of water vapour.

Heat is the irregular haphazard motion of molecules, and a rise in temperature of a substance merely means that its molecules come to move about and bump into each other with greater violence than they did when the substance was cooler. Let us see what this means in the case of a gas which is enclosed in a container. All the molecules move about wildly, continually running into each other and bouncing off each other like a huge swarm of miniature tennis balls. Some of them, of course, bounce against the solid walls of the container and try to push them out of the way. The hotter the gas is, the more violently the molecules hammer against the walls and if part of the container wall is movable, as is the piston in the cylinder of a petrol engine, the molecules of the hot gas will push it away. So the work



done by the piston and connecting rod, turning over the crankshaft of the engine, originates from the multitude of tiny hammer blows which the molecules of the expanding gas deal the piston.

But thermal expansion—expansion due to heating—is not confined to gases. It is a property shown, with a very few exceptions, by all substances, gaseous, liquid and solid. In contradistinction to what happens with a gas, in a solid body the molecules hold on to each other by attraction forces which keep the molecules together in a regular pattern. In this pattern, which is responsible for the beautifully regular shape of crystals, each molecule stays in its assigned place. But it does not stand quite still; it vibrates like the end of a tuning fork around a position of rest. This vibration is the heat motion of the molecule and the more the solid body is heated, the more violent this vibration becomes. The vibration tends, of course, to push the molecules apart; that means the body will expand.

You can observe and measure this expansion in a very simple experiment. Place one side of a metal bar against a stop and the other side on a roller (for instance a knitting needle), to the end of which you have attached a pointer. When you heat the bar with a flame the pointer will move and will return to its original position when you allow the bar to cool again.

K.M.

Far and Near

U.S.S.R. Academy of Sciences Meeting

THE 220th anniversary of the Russian Academy of Sciences was attended by many foreign scientists; 17 countries were represented and the sessions took on a truly international character. The British delegation comprised the following:

Professor N. K. Adam, Professor E. N. da C. Andrade, Professor E. D. Adrian, Professor Max Born, Professor V. Gordon Childe, Dr. E. M. Crowther, Professor F. G. Donnan, Mr. W. N. Edwards, Professor C. N. Hinshelwood, Sir Thomas Holland, Dr. J. S. Huxley, Sir Harold Spencer Jones, Dr. Alex Muir, Dr. W. G. Ogg, Lord Radnor, Sir Robert Robinson, Professor A. Sorsby, Professor R. H. Tawney, Dr. Henry Thomas, Professor D. M. S. Watson, and Dr. W. A. Wooster.

Eight other British scientists were due to go but they were unable to leave the country owing to the exit permits, for which application had been made many days before, being refused. (This ban is the subject of a note on the first page of this issue.) The scientists concerned were: Professor J. D. Bernal, Professor P. M. S. Blackett, Sir Charles Darwin, Professor P. A. M. Dirac, Professor E. A. Milne, Professor N. F. Mott, Professor R. G. W. Norrish, and Professor E. K. Rideal.

The opening session of the anniversary meeting was held in the Grand Opera House of Moscow.

In his presidential speech Academician Vladimir Komarov stressed the connection between science and everyday life. He described the Academy as the scientific centre of the U.S.S.R. and mentioned some of the most notable work done by Russian scientists during the last twenty years, referring in particular to the researches of Kapitsa, Kurnakov, Zelinsky, Favorsky, Bach, Krylov, Vinogradov and Obruchev. He emphasised that all these achievements were closely connected with socialist construction, and said they were the result of the exceptional care and attention paid to science by the Soviet Government. He made a special point of the fact that scientific ties had been increased and strengthened during the war. The ideas of freedom and democracy, he went on, had been the guiding star of leading circles of British society during the epoch of the development of natural science in England, and freedom of scientific creation had been the banner of the London Royal Society, the centre of European scientific thought. These democratic ideas inspired the great works of Bacon, Newton, Faraday, Maxwell, Darwin and other English scientists. The history of Russian science was bound up with the English. The works of Darwin met with a wide response among scientific and public circles in Russia, Darwin himself guiding the first steps of the brilliant pleiad of Russian evolutionists. British science highly appraised the works of Mendeleyev, Timiryazev, Pavlov, Lebedev and Russia's other outstanding natural scientists. During the war Soviet scientists had striven to strengthen and develop the ties with English science. Academician Komarov further spoke of the traditional ties of friendship between the scientists of the Soviet Union and those of America and France, and the close friendship binding them with the scientists of the Slav countries.

A review of the Academy's history was then made by Academician Bruyevich, and a report on the achievements in geology and geography was read by Academician Obruchev.

Foreign scientists took part in the ensuing sessions; for instance, at the session covering soil science Dr. Ogg of Rothamsted, Dr. Kellogg of the U.S. Department of Agriculture and the French scientist, Dr. Demolon, contributed papers. The visitors also saw some of the research institutes of Moscow and Leningrad, including the Institute of Physical Problems of which Professor Kapitsa is director, and there they had the opportunity of seeing the new method of liquifying air by means of Kapitsa's turbodetander.

One thousand one hundred Soviet and foreign scientists travelled on June 24 to Leningrad where the anniversary meeting was continued. Among the places they visited were the Leningrad suburbs where so few months before fighting was taking place, and the State Hermitage Museum.

In a broadcast over the Moscow radio one of the United States delegation, Dr. J. Heyman of Columbia University, gave some impressions of the hospitals and medical research laboratories that he had visited. He spoke of the widespread interest the Russian people took in science, and commented on the fact that the newspapers devoted pages to items of scientific interest. "Science and reason has replaced superstition," said Dr. Heyman.

Scientific Attachés Unnecessary?

THE Parliamentary and Scientific Committee has received a reply from the Foreign Office dealing with the committee's recent memorandum on scientific attachés for the diplomatic service. The reply, which came from Mr. Richard Law, says that the Foreign Office holds that "a good deal more inquiry into the exact role which the proposed scientific attachés should fill" is needed. "It is not yet clear to us", writes Mr. Law, "that the various objects set out in the memorandum can best be attained by placing, on diplomatic missions, responsibilities which are not fundamentally appropriate to them and which might perhaps be better fulfilled in other ways."

Careers in Science

THE Ministry of Labour and National Service has prepared a number of pamphlets about careers. Intended primarily for the guidance of Servicemen and women, they have been made available to the general public and can be purchased, price 3*d*. each, from the Stationery Office. No. 37 in the series deals with careers in science, and covers physics, chemistry, biology, geology and metallurgy. Over forty such pamphlets have been published; chemical engineering, pharmacy, medical laboratory technology, oil production, dentistry, and medicine are all subjects with separate pamphlets to themselves.

The Colonial Office has issued two pamphlets dealing with careers in the Colonial Service. One of them (the code letters for this document are RDW/M) deals ostensibly with technical posts filled by the Crown Agents for the Colonies, but contains little real information. The other however (code letters RDW/6) is a 24-page document and gives some useful details about qualifications, salaries, etc., in agriculture, forestry, education, engineering and architecture, and medicine.

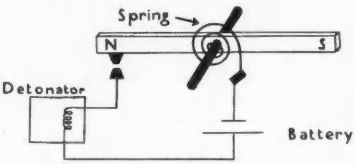
National Certificate in Applied Physics

THE announcement by the Ministry of Education of a scheme for the award of Ordinary and Higher National Certificates in applied physics brings to fruition one of the recommendations made in the report by the Institute of Physics on Education and Training issued in 1943. Prospective students may obtain further particulars of the courses from their local technical colleges or local director of education. The courses are designed not only to lead to a well recognised qualification in the National Certificate, but at the same time to be of particular benefit to the student by the additional knowledge he will gain. Only a bare outline of the type of approved course has so far been released by the Institute of Physics. The three-year part-time course for the Ordinary National Certificate must include Mathematics, Physics and Chemistry, and in the first year a special course (not the orthodox engineering one) in Workshop Practice and Drawing. The Physics in the course is to be treated realistically and the principles are whenever possible to be illustrated by practical examples drawn from the industries in which the students are working. The course in Applied Physics in the final year is to be related to the local industries. English is not included formally as a subject in the course, but in all classes attention is to be paid to its correct use.

The course for the Higher National Certificate must be a two-year part-time one and must aim at reaching a standard in the several branches of Physics corresponding to that required for a degree in the subject at pass standard. It will include Mathematics and a special subject related to the student's daily work in local industry.

Beating the Magnetic Mine

SOME interesting facts have recently been revealed about how the menace of the magnetic mine was overcome by the combined efforts of the Admiralty Research Department and two famous cable firms.



The German magnetic mine, a development of a type used in the first World War, has a small magnet pivoted so that it can rotate in a vertical plane instead of the normal horizontal plane of a compass needle. North of the equator such a magnet, if pointing North and South, will dip its North Pole downwards, the amount of the dip increasing with the distance from the equator. In the mine a small spiral spring acts against the dip so as to keep the magnet horizontal, but when an iron ship passes overhead the strength of the magnetic field is increased and the magnet dips. This is arranged to make an electrical contact which detonates the explosive in the mine. (See diagram).

At first individual ships were protected by a "degaussing girdle" which neutralised the effect on the magnetic field, but this left the mine a danger to unprotected shipping.

After many experiments a method was devised which would explode the mines on the sea bed. Two mine-sweepers, each protected by a "degaussing girdle," proceed on parallel courses, each trailing a short and a long length of buoyant cable. Generators on board send surges of electricity down the cables, the circuit between these ends being completed by the sea itself. A high current flows during the surge and sets up a magnetic field in the sea powerful enough to dip the magnets and thus explode all the mines in the area between the two ships' cables.

The manufacture in quantity of cable which would carry the heavy currents and also float was in itself a problem. One successful solution was the use as a core of an inflated rubber cylinder (this was manufactured with the same machinery that normally produces tennis balls), on which the copper conductors were wound. A rubber sheath formed the outer cover and special electrodes were fitted to the ends to minimise the electrical corrosion which occurred when the heavy currents were passed.

The method is even more efficient than normal mine-sweeping of non-magnetic mines since the cables are not damaged by the exploding mines.

The Penicillin Film

THE FILM on penicillin, the preparation of which was announced in DISCOVERY as long ago as May of last year, has at last been released. Although a good production, this tardy appearance inevitably detracts from its merits. A film on penicillin would have been much more welcome a year ago than it is to-day. Prompter action could have done much to place the facts of this important discovery in their proper perspective and given British workers the credit they so rightly deserve. Through our bad management of publicity, the Americans, who came into the field only after the pioneer work had been done here, have stolen much of our thunder. This, it must be emphasised, is not due to any deliberate attempt on their part to minimise British contributions but arose from the fact that they quickly realised the tremendous importance of penicillin and gave it a big build-up almost from the start. For their publicity material they naturally turned to their own laboratories and factories as the easiest source. The bulk of their publicity has sadly overshadowed our own meagre output of information on penicillin. The true facts have been made even more difficult for the layman to appreciate since over 90 % of the world's supply of the drug is being made in American factories, a state of affairs which conflicts curiously with its discovery and development entirely in this country.

This film, late though it is, should do much to show the history of penicillin in its proper light. The central figure of the film is a British soldier who is seriously injured in the fighting in Holland. Realistic shots show first-aid in the field and the early application of blood transfusion, the latter representing another important advance in medical technique. At the Casualty Clearing Station administration of penicillin is started, apparently as a prophylactic rather than for disposing of any proved infection, and is continued until wound healing is well advanced. One cannot help feeling that the value of penicillin could have been more convincingly demonstrated by centring the film round a case of active infection.

From the battlefield introduction the story is switched back to the discovery and development of penicillin. Professor Sir Alexander Fleming himself shows how his attention was first directed towards the famous staphylococcal culture contaminated with *Penicillin notatum* and his original research is outlined. Then the scene shifts to the Sir William Dunn School of Pathology, Oxford, where the investigation of penicillin was re-opened nearly ten years later. The reasons underlying the failure to develop penicillin at the time of its discovery could have been made clearer but once the gap has been bridged the pioneer work at Oxford is well tackled. Members of the

original research team, headed by Professor Sir Howard Florey and Dr. E. Chain, are seen working in their own laboratories and the complexity of the problem, needing the collaboration of experts in many different fields, is well brought out. The original method of penicillin production for research purposes in Oxford is accurately described.

After illustrating the early laboratory work the film switches to modern clinical use. At this point much more could have been made of the powers of penicillin to deal with infections such as pneumonia. meningitis and venereal diseases which are deadly at all times. One is rather left with the impression that penicillin is extremely useful in wartime but has not nearly so exciting a role to play in peace.

The production of penicillin is then illustrated. It is unfortunate that even now, when American firms have successfully used deep fermentation methods for more than two years, a new British film has to be content with illustrating our industrial production with bottle or tray plants in which the mould is grown as a surface culture. (Incidentally the only ampoules of penicillin of which we get a close-up view are of American origin *from a factory using deep tank methods*.)

At the end of the film the scene shifts back to Oxford and other laboratories in which the chemical investigation of penicillin has been pursued. While mention is made of the possibility of synthesis now that the structural formula has been established it is rightly pointed out that in spite of intensive work the solution of this problem cannot be expected in the immediate future.

While shortcomings are apparent to those who are thoroughly familiar with the penicillin story the film as a whole runs smoothly and convincingly. The photography and the technical background are excellent. The producers have been fortunate in having the active collaboration of many of the original research workers, particularly Sir Alexander Fleming and the Oxford team. With such backing and interest it is not surprising that serious factual errors have been entirely avoided.

Penicillin, sponsored jointly by I.C.I. and the Therapeutic Research Corporation, is produced by the Realist Film Unit and runs for slightly over fifteen minutes. It was directed by Alexander Shaw and Kay Mander. Taken as a whole it is useful instruction and good entertainment. It should be well received, and deserves a wide distribution.

Teaching Science

THE Essex Science Teachers' Association, of which Lord Rayleigh, F.R.S., is president, has produced an interim report dealing with the content of the science curriculum in post-primary schools. The report argues very cogently not the need but the *necessity* for teaching science in this age of applied science—"just as an educated adult ought to be able to appreciate a well-written story or a well-produced film, so he should be able to understand the significance of a striking biological discovery or engineering advance (such as, the use of penicillin or the development of jet-propelled aircraft)". The logical way of thinking that should emerge from the study of science is stressed as something valuable in the ordinary situations of daily life, with the reservation, however, that "only if our pupils are interested will they remember our lessons and become sufficiently enthusiastic about them to carry them over into another field". Small classes are advocated; 20 should be the maximum for practical classes, it is recommended, and the point it made is that it would be well worth investigating whether classes of 10 or 12 pupils could be arranged. The Association intends to publish a separate report on laboratory accommodation.

Fly Bombs upset Genetics Research

THE substantial damage at John Innes Horticultural Institution due to flying bombs is revealed in the 35th annual report. In June 1944 the first bomb fell nearby, and among the casualties was Miss Pratt, assistant secretary to the Institution's council, who was killed. In the course of the following two months eight flying bombs damaged buildings and private houses of the Institution. The glass from most of the glasshouses was blown out. In the main laboratories and offices the ceilings were brought down, and, says the report, "the general scene was one of appalling desolation". Yet no books in the Institution's famous library were destroyed, and no apparatus except an X-ray valve and a mercury vapour lamp! But the greater part of the breeding work of the year was spoiled; out of 28 kinds of plants grown outside for research purposes, nine were damaged or destroyed, and in the greenhouses 4 out of 12 kinds of plants suffered.

A new venture by the institution's enterprising director, Dr. Darlington, is the publication of a *John Innes Bulletin*, the first number of which is now available, price 2*s*. 6*d*. Entitled "Answers to Growers", it contains articles full of useful information on a number of subjects; What is the use of hoeing?—Does composting destroy virus?—What is the best leaf mould?—What varieties of sweet corn are profitable?—What are the best plums to grow?—these are some of the questions answered in the bulletin. There is a long article by Mr. W. J. C. Lawrence about the effect of different treatments on seedlings, and a contribution on dwarf and bush tomatoes by Mr. M. B. Crane, who elsewhere deals with two pathological conditions in the Lord Lambourne apple which he suggests are in the nature of viruses and have originated by grafting. The bulletin is excellently illustrated. (Any reader who wishes to obtain a copy should write to The Director, John Innes Horticultural Institution, Mostyn Road, London, S.W.19).

Personal Note

MR. N. CLARKE, B.Sc., A.Inst.P., has been appointed Assistant Secretary of the Institute of Physics.

Night Sky in August

The Moon.—New moon occurs on August 8d. 00h. 32m. U.T., and full moon on August 23d. 12h. 03m. The following conjunctions take place:

August			
2d. 23h.	Mars in conjunction with the moon,		Mars 2°N.
4d. 16h.	Venus	,,	Venus 1° S.
5d. 23h.	Saturn	,,	Saturn 1° s.
9d. 07h.	Mercury	,,	Mercury 9°N.
11d. 06h.	Jupiter	,,	Jupiter 4° S.
31d. 13h.	Mars	,,	Mars 0.9°N.

In addition to these conjunctions with the moon, Venus is in conjunction with Saturn on August 22d. 04h., Venus being 0.7° S.

The Planets.—Mercury sets at 20h. 18m., 19h. 06m., and 18h. 02m. at the beginning middle, and end of the month respectively, but as this is after sunset in the last two cases the planet will not be well placed for observation in these circumstances. On August 5 and 29 Mercury is stationary, and on August 20 in inferior conjunction. Venus rises in the early morning hours during August—at 1h. 11m., 1h. 22m., and 1h. 50 m. at the beginning, middle, and end of the month respectively—and will be conspicuous in the eastern sky. Mars, in the constellation of Taurus, rises at 23h. 47m., 23h. 20m., and 22h. 54m., at the beginning, middle, and end of the month respectively. Jupiter sets about an hour and a half after the sun on August 1 and about an hour after the sun on August 15. At the end of the month the planet sets less than three-quarters of an hour after the sun and is not favourably placed for observation. Saturn rises at 2h. 37m., 2h. 16m., and 0h. 56m. at the beginning, middle, and end of the month, respectively. In the early part of August the planet is close to δ Geminorum. Saturn's distance from the earth varies between 928 and 903 million miles from August 1 to 31.

Times of rising and setting of the sun and moon are given below, the latitude of Greenwich being assumed:

August	Sunrise	Sunset
1	4h. 22m.	19h. 49m.
15	4h. 44m.	19h. 24m.
31	5h. 10m.	18h. 50m.
August	Moonrise	Moonset
1	23h. 28m.	13h. 31m.
15	12h. 37m.	22h. 28m.
31	23h. 19m.	15h. 31m.

The Perseid meteors are due in August, and the shower reaches its maximum on August 10-12. The radiant is at R.A. 3h., Dec. + 57°.

M. DAVIDSON, D.SC., F.R.A.S.

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